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TRANSPORTATION CONTROLS TO REDUCE MOTOR VEHICLE EMISSIONS IN MINNEAPOLIS AND ST. PAUL, MINNESOTA

Fred Winkler

GCA Corporation

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16. Abstracts
The document demonstrates the nature of the Air Quality problem attributed to motor vehicle operation, the magnitude of the problem and a strategy developed to neutralize these effects in order that National Ambient air quality standard may be attained and maintained.

17. Key Words and Document Analysis. 17a. Descriptors

Motor Vehicle emitted pollutants - air pollutants originating within a motor vehicle and released to the atmosphere.

National Ambient Air Quality Standards - Air Quality Standards promulgated by the Environmental Protection Agency and published as a Federal Regulation in the Federal Register.

17b. Identifiers/Open-Ended Terms

VMT - Vehicle Miles Traveled
Vehicle Mix - distribution of motor vehicle population by age group.
LDV - light duty vehicle - less than 6500 lbs.
HDV - heavy duty vehicle - greater than 6500 lbs.

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Prepared by

GCA Corporation
GCA Technology Division
Bedford, Massachusetts

Contract No. 68-02-0041

EPA Project Officer: Fred Winkler

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Office of Air and Water Programs
Office of Air Quality Planning and Standards
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December 1972

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I. INTRODUCTION AND SUMMARY

A. BACKGROUND

States were required to submit implementation plans by January 30, 1972, that contained control strategies demonstrating how the national ambient air quality standards would be achieved by 1975. Many urban areas could not achieve the carbon monoxide and oxidant air quality standards by 1975 or even 1977 through the expected emission reductions from the 1975 exhaust systems control. Major difficulty was encountered by many states in the formulation of implementation plans that included transportation control strategies (including, for example, retrofit and inspection, gaseous fuel conversions, traffic flow improvements, increased mass transit usage, car pools, motor vehicle restraints, and work schedule changes.) Because of the complex implementation problems associated with transportation controls, states were granted until February 15, 1973, to study and to select a combination of transportation controls that demonstrated how the national air quality standards would be achieved and maintained by 1977.

B. PURPOSE, SCOPE AND LIMITATIONS OF STUDY

The purpose of the study reported on herein was to identify and develop transportation control strategies that will achieve the carbon monoxide and oxidant air quality standards required to be met by Minnesota in the Minneapolis-St. Paul metropolitan area by the year 1977. The results of the study were to help determine the initial direction that the State of Minnesota should take in selecting feasible and effective transportation

controls. It was anticipated that the control strategies outlined in this study would be periodically revised in the coming years. Existing state implementation plans were analyzed to verify and assess the severity of the carbon monoxide and oxidant pollutant problems, and the most promising transportation controls and their likely air quality impact were determined. Major implementation obstacles were noted after discussions with those agencies responsible for implementing the controls, and finally, a surveillance review process (January, 1973 - December, 1976, inclusive) was developed for EPA to use in monitoring implementation progress and air quality impact of transportation control strategies.

It should be noted that the study was carried out relying on the best data and techniques available during the period of the study and further, that a large number of assumptions were made as to the nature of future events. The 1977 air quality predictions were based on extant air quality data and on predicted stationary source emissions and predicted traffic patterns; these predicted parameters themselves were based on anticipated emission control techniques, anticipated growth patterns, and the assumed outcome of unresolved legal and political decisions. Further, the development, ranking and selection of transportation controls were based on extant and predicted economic, sociological, institutional and legal considerations. Finally, the surveillance process presented in this report, although showing key checkpoints towards implementation of the recommended controls, is in itself dependent upon the same assumed pattern of future events.

It should be emphasized therefore, that to the extent that the timescale of the recommended program permits, the conclusions and recommendations of this report should not be construed as a program which must be rigidly followed until 1977, but rather it should be regarded first, as a delineation as to what appears at the present time to be a feasible course of action to attain air quality goals, and secondly, as a framework upon which an optimum on-going program can be built as new data and techniques become available, as legal and political decisions are made, and as the assumptions as to future events are, or are not, validated.

C. CONTENT OF REPORT

Section II of this report describes how the pollutant concentration levels which could be expected to occur in 1977 in the Minneapolis-St. Paul area were predicted. These levels were determined by an adaptation of the proportional model using motor vehicle emissions from traffic patterns predicted for 1977 together with predicted non-vehicular emissions for 1977 obtained from state agencies. Comparison of these predicted 1977 air pollutant concentrations with the national air quality standards enabled the computation of the motor vehicle emissions which would result in the air quality standards being met, and therefore, to what extent, if any, reductions in the predicted 1977 motor vehicle emissions would be required. In order to determine the pollutant concentration(s) which was to serve as the basis for the proportional model, an intensive evaluation of all existing meteorological and air quality data was performed.

The final determination as to the concentration value used was made in close cooperation with representatives of local and state agencies and of EPA.

Section III describes how candidate control strategies were developed, evaluated and ranked having regard to technical, legal, institutional, sociological and economic criteria. An important feature of this task was the continuing interaction between, on one hand, the GCA study team, and on the other hand, representatives of local and state environmental planning and transportation agencies, concerned citizen's groups, and EPA representatives.

Section IV deals in detail with the obstacles to the implementation of the candidate strategies. These obstacles include legal authorization and requirements; financial requirements; management and enforcement responsibility; political feasibility; economic impact and user acceptance.

Section V presents the rationale for selecting the optimum package of controls necessary to achieve the required reduction in motor vehicle emissions and also presents the confirmed effect on air quality.

Section VI presents the surveillance review process which will enable EPA to monitor the implementation progress and air quality impact of the recommended strategies. A curve showing predicted air quality levels for the years 1973 to 1977 and beyond is presented, based on the implementation of the recommended transportation controls. This will provide a basic indication of the way in which air quality should improve as time passes and as controls are implemented. In addition, important checkpoints are provided delineating

the salient actions which must be taken in order to imlement the strategies such as the obtaining of the necessary financing and legislation. Further, important background assumptions, such as growth rate are identified, and methodologies supplied, to provide verification that these assumptions are in fact, validated during the course of the program.

It should be noted, however, that the surveillance process thus provided is of necessity based on the problem, and the concomitant transportation controls as they are presently perceived. An equally important part of any surveillance process is the continuing reassessment of both the problem itself and the appropriateness of the required controls. As was discussed earlier in this Introduction, the present study employed a whole range of both of extant data and techniques, and also of assumptions about the course of future events. This data base should be continuously reviewed as new information becomes available. Thus, although the key background parameters are called out in the Surveillance Process, a thorough and continuing review of all the data, techniques and assumptions contained in this report will be required to properly update the problem definition and appropriate control measures.

D. SUMMARY OF PROBLEM AND REQUIRED TRANSPORTATION CONTROLS

1. Oxidant Air Quality and Hydrocarbon Emissions

The one hour average oxidant air quality standard will be achieved by 1977 in the Minneapolis-St. Paul metropolitan areas, including the two CBD's as seen in Tables I-1 and I-2. This standard will be

TABLE I-1

SUMMARY OF OXIDANT AIR QUALITY AND HYDROCARBON EMISSIONS IN MINNEAPOLIS CBD

A. Area = 2.2 sq. miles

B. Hydrocarbon Emissions (kg/12 hrs) and oxidant levels (ppm)

	1971	1977 Without Strategy
Vehicle Emissions	3,560	1,720
Non-Vehicular Emissions	1,540	1,840
Total Emissions	5,100	3,560
Oxidant level (1-hr average)	0.114	< 0.08

TABLE I-2

SUMMARY OF OXIDANT AIR QUALITY AND HYDROCARBON EMISSIONS IN ST. PAUL CBD

A. Area = 0.8 sq. miles

B. Hydrocarbon Emissions (kg/12 hrs) and oxidant levels (ppm)

	1971	1977 Without Strategy
Vehicle Emissions	1,290	620
Non-Vehicular Emissions	560	670
Total Emissions	1,850	1,290
Oxidant level (1-hr average)	0.114	< 0.08

achieved as a result of the hydrocarbon emission reductions obtained from the Federal Motor Vehicle Control Program. In determining that the oxidant standard would be achieved by 1977, GCA took the conservative approach of not considering the application of non-vehicular control strategies for hydrocarbons. With the application of such non-vehicular control strategies, the achievement of the oxidant standard by 1977 would be further assured.

2. Carbon Monoxide Air Quality and Emissions

8-hour average CO air quality standards will be achieved by 1977 in the Minneapolis-St. Paul metropolitan area with the exception of the Minneapolis CBD and St. Paul CBD, with the CO emission reductions obtained from the Federal Motor Vehicle Control Program. Tables I-3 and I-4 summarize the emissions and air quality in the two CBD's with and without the application of the recommended control strategies.

3. Control Strategies

The following Transportation Control strategies are recommended and their impact is summarized in Tables I-3 and I-4.

MINNEAPOLIS CBD

Strategy 1: Fringe parking combined with people mover system estimated to reduce 1977 light duty VMT's by 8%.

Strategy 2: Traffic surveillance and control estimated to increase average speed in Minneapolis CBD from 14 mph to 20 mph by 1977.

TABLE I-3

SUMMARY OF CARBON MONOXIDE AIR QUALITY AND EMISSIONS IN MINNEAPOLIS CBD

A. Area = 2.2 sq. miles

B. CO emissions (kg/12 hrs) and air quality levels (ppm)

	1971	1977 Without Strategy	1977* With Strategy #1 Only	1977* With Strategies #1 & #2	Without Strategies 1978	Without Strategies 1979
Vehicle Emissions	27,960	14,116	13,316	10,016	11,912	10,008
Non-Vehicular Emissions	240	284	284	284	288	292
Total Emissions	28,200	14,400	13,600	10,300	12,200	10,300
CO level (8-hr average)	18.9	9.7	9.1	6.9	8.2	6.9

*See text (Section I D 3) for description of control strategies.

TABLE I-4

SUMMARY OF CARBON MONOXIDE AIR QUALITY AND EMISSIONS IN ST. PAUL CBD

A. Area = 0.8 sq. miles

B. CO emissions (kg/12 hrs) and air quality (ppm)

	1971	1977 Without Strategy	1977 * With Strategy #1 Only	1977 * With Strategies #1 & #2	Without Strategies 1978	Without Strategies 1979
Vehicle Emissions	10,013	5,097	4,697	3,597	4,295	3,594
Non-Vehicular Emissions	87	103	103	103	105	106
Total Emissions	10,100	5,200	4,800	3,700	4,400	3,700
CO level (8-hr average)	18.6	9.5	8.8	6.8	8.1	6.8

*See text (Section I D 3) for description of control strategies.

ST. PAUL CBD

Strategy 1: Fringe parking combined with shuttle bus service estimated to reduce 1977 light duty VMT's by 10%.

Strategy 2: Traffic signal system estimated to increase average speed in St. Paul CBD from 12 mph to 18 mph by 1977.

II. VERIFICATION AND ASSESSMENT OF AIR POLLUTION PROBLEM

A. OUTLINE OF METHODOLOGY

The basic procedure employed was to develop, for each city,* pollutant concentration levels which could be expected in 1977 without the application of transportation controls. Pollutant levels were determined by the proportional model using non-vehicular emissions supplied by state agencies and using vehicular emissions based on traffic data developed during the course of this study. More sophisticated techniques could not be employed due to the lack of suitable extant calibrated diffusion models, and the short time period of the contract which precluded the development of a suitable model and the required inputs. Comparison of potential 1977 air quality levels with the appropriate standard gave the allowable motor vehicle emissions in 1977, which in turn formed the basis for the development of transportation control strategies.

Emissions from non-vehicular sources were obtained from state implementation plans updated as required from available information supplied by state agencies. Emissions from vehicular sources were computed following the recommendations given in EPA draft publication An Interim Report on Motor Vehicle Emission Estimation by David S. Kircher and Donald P. Armstrong, dated October 1972. Air quality data for each sensor within the city area was reviewed and evaluated in close cooperation with

*In this discussion, the word city is used to denote the urban area covered by the study and is not restricted to the area within the political limits of the city.

state and local agencies. The instrumental method and sensor location was studied and records of instrument maintenance and calibration examined so as to identify questionable readings. Meteorological records were then examined and compared with seasonal and diurnal variations in air quality levels. Finally the pollutant concentrations which would form the basis for the proportional rollback calculations were decided upon in concert with state and local agencies and EPA representatives. The year in which this concentration level occurred defined the base year for the proportional rollback calculations.

Because of the differences involved, the detailed methodologies for carbon monoxide and oxidants are presented separately below.

1. Methodology for Carbon Monoxide

Because ambient concentrations of carbon monoxide at any given location appear to be highly dependent on carbon monoxide emissions in the near vicinity, it was felt that some justification existed for a modification of the proportional model. It was felt that in order to reduce ambient CO levels in, for example, a central business district (CBD), it would be more appropriate to roll back CO emissions in the CBD itself, rather than the entire air quality region. The assumption was therefore made that pollutant concentration in any given zone was directly proportional to the emission rate of that pollutant emission within that zone. Accordingly, each city area was divided into Urban Activity Districts (UAD's) - about the size of the central business district (CBD) in the center of the city with increasingly larger UAD's towards the suburban

areas. These Urban Activity Districts are the same as those utilized by the Metropolitan Council, the planning agency for the seven counties comprising AQCR 131.

An emission density/concentration ratio (e/c ratio) was assigned to the sensor located in downtown Minneapolis, the e/c ratio being based on the total CO emission density (expressed in kg/sq. mile/12 hrs.) for the base year within the Minneapolis CBD, and the CO concentration value which formed the basis of the proportional rollback computations. Based on the e/c ratio so obtained, the maximum allowable emission density was derived which corresponded to the national air quality level to be achieved (i.e., 9 ppm for an 8-hour average). A map showing the CO emission densities for each UAD was then prepared for the year 1977, based on the predicted vehicular and non-vehicular emissions for that year. Vehicular emissions were based on predicted traffic patterns in the absence of any transportation controls imposed in order to meet national air quality standards for CO (the "no strategy case"). Non-vehicular emissions for the years of interest were obtained from state implementation plans and state agencies, and take into account predicted growth. Non-vehicular control strategies for CO, however, were not considered in predicting 1977 CO emissions primarily because of the small contribution of the non-vehicular emissions to total CO emissions (~ 1%).

From this map, the zones in which emissions exceeding the maximum allowable density were identified, and the level of emission reductions necessary to meet the CO standard were determined.

2. Discussion of Methodology for Carbon Monoxide

a. Modified Proportional Model

Modified proportional model applications and the limitations of the conventional proportional rollback method have been well documented and reviewed[1] and need not be discussed further here. The technique used in the present study was an extension of the conventional rollback technique to the extent that it was assumed first, that the constant of proportionality between emissions and concentration may be derived from emissions emanating from the relatively small area around the sensor (the traffic zone), and second, that this constant of proportionality (the emission/concentration ratio) could be applied to determine pollutant concentrations in other zones of comparable area on the basis of the pollutant emissions in those zones.

Some justification of the first assumption can be found, for example, in recent work of Hanna* and Gifford** who demonstrate the dominance of urban pollution patterns by the distribution of the local area sources. The success of their urban diffusion model, in which concentration is simply directly proportional to the area source strength

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[1] Noel de Nevers. Rollback Modeling, Basic and Modified. Draft Document, EPA, Durham, N.C. (August 1972).

* Hanna, S.R., "A Simple Method of Calculating Dispersion from Urban Area Sources." J. APCA 21, 774-777 (December 1971).

** Gifford, F.A., "Applications of a Simple Urban Pollution Model," (paper presented at the Conference on Urban Environment and Second Conference on Biometeorology of the Amer. Meteor. Soc., October 31 - November 2, 1972, Philadelphia, Pa.).

and inversely proportional to wind speed, is attributed largely to the relatively uniform distribution of emission within an urban area and the rate at which the effect of an area source upon a given receptor decreases with distance. In the proportional model, meteorological effects, such as wind speed, are assumed to be duplicated over one-year periods. The validity of the second assumption depends, in large part, upon the extent to which diffusion and transport parameters are uniform from zone to zone - a factor which could not be investigated because of the constraints of the program. Thus, it was felt that, in the absence of a more sophisticated technique, the use of this extension to the proportional model was justified first, to obtain some assessment as to whether the existing sensors were located in the hot-spots, and second, to obtain some assurance that transportation strategies intended to reduce emission densities in one zone (to the level required to meet ambient standards) did not increase emission densities to unacceptable levels in adjacent zones.

As might be expected, where an urban area had several sensors, the emission concentration ratios were widely different and this served to underline the fundamental limitations of the technique employed. An implicit assumption in the technique employed was that the air quality in a traffic zone could be fairly represented by one concentration level and that this level depended only upon the average emission density within that zone. The two major factors mitigating against this assumption are:

(a) Emission densities are not uniform across even a small traffic zone.

(b) Concentration levels are not uniform across the traffic zone partly because of the lack of uniformity of emission density and partly because the point surface concentrations are affected by micrometerology and microtopography as well as emission density.

Considerable judgment had to be used, therefore, both in the derivation of e/c ratios and in their subsequent use. In heavily trafficked downtown areas the variation was judged not to be too great, so that the single recorded concentration might reasonably be expected to be representative of the zone's air quality and emission density. However, in suburban zones having overall low traffic densities, sensors are often placed at very localized hot spots, such as a traffic circle, so that the recorded concentration levels were neither representative of the overall air quality nor of the overall emission density in that zone.

Accordingly, e/c ratios were generally derived from sensors in the central areas of the cities and applied to suburban areas for the prediction of 1977 concentration levels. This procedure gave air quality levels which were generally representative of the suburban zone. However, it must be realized that control strategies based on this procedure, while they may ensure that the overall air quality in a suburban zone will not exceed ambient standards, do not preclude the occurrence of higher concentrations in very localized hot spots such as might occur in the immediate vicinity of a major traffic intersection.

b. Seasonal and Diurnal Variations

The carbon monoxide concentration level chosen as the basis for the base year e/c ratio in any zone was the highest valid 8-hour average observed during the base year. The 1-hour average either never exceeded the standard or was very much closer to the standard than the 8-hour average, so that controls required to meet the 8-hour standard would also result in the 1-hour standard being met. Motor vehicle emissions over 24 hours, 12 hour and max. 8-hour periods were compared with sensor readings and the most appropriate period of time selected on which to base calculations of emission density. Although seasonal variations in readings were noted, traffic data was not available on a seasonal basis, so that vehicle emissions were based on annual average work day traffic data.

c. Background Concentrations

Background concentration levels of CO were not taken into account. Where a zone was located near a large point source, simple "worst case" diffusion calculations were performed to assess the effect of the point source on the zone. In all cases, it was found that this contribution was negligible. Where a zone actually contained a large point source such as UAD 93 in which the St. Paul Airport is located, its emissions were found to be much greater than automotive emissions within the zone and any problem in that zone was regarded as due primarily to the stationary source.

3. Methodology and Discussion for Oxidants

The technique employed for oxidants was basically the same as has just been described for CO. Even though there is a significant length of time required for the formation of oxidants from hydrocarbon emissions, the GCA staff felt that the areas of high emission density i.e., the Minneapolis and St. Paul CBD areas, were the primary cause of excessive oxidant concentrations observed anywhere in the metropolitan area.

The reductions in hydrocarbon emissions necessary to achieve oxidant ambient standards were obtained from Appendix J, Federal Register of August 14, 1971.

B. DISCUSSION OF 1971 AIR POLLUTION LEVELS

1. Background

The Implementation Plan submitted to EPA by the State of Minnesota (MPCA) showed that the cities of Minneapolis and St. Paul cannot meet the more stringent 8-hour average national ambient CO standard by 1975. The Plan did show, however, that the Photochemical Oxidant standard can be met by 1975 throughout the state. EPA has, as discussed earlier in this report granted MPCA a two-year extension to achieve the CO standard by the application of appropriate transportation control strategies. This section of the report reviews and analyzes the CO and photochemical oxidant air quality data contained in the Implementation Plan as well as collected after the submission of the Plan, to assess the reductions required from motor vehicle emissions to achieve the air quality standards for both CO and photochemical oxidants by 1977.

2. The Natural Features of Minneapolis-St. Paul

a. General

The Minneapolis-St. Paul Metropolitan area is situated on a gently rolling plain with many lakes and ponds, where the Minnesota and St. Croix Rivers intersect the Mississippi River. The general level of the land is less than 1000 feet above sea level. This physiological feature is favorable to the dispersion of contaminants through diffusion and other favorable climatic conditions.

The type of climate is controlled by the interrelationship of the continental polar air and warm moist air from the Gulf of

Mexico. The results are wide variations in temperature and a general tendency to reach the extremes in all climatic features. There are great seasonal temperature variations ranging from very cold in the winter to very warm in the summer. The average mean temperature for the four seasons for the period 1931 to 1955 was: winter 14°F, spring 42°F, summer 68°F, and fall 46°F.

b. Meteorology

The three conditions of low wind speeds, temperature inversions and condensation, particularly affect the dispersion of a contaminant. A simultaneous occurrence of all three results in severe levels of air pollution.

The wind speed in the Minneapolis -St. Paul area averages just little over 10 miles per hour with little variation in monthly averages as seen in Table II-1. Figure II-1 shows that the predominant wind prevails from the northwest in winter and southeast in summer. Lower wind speeds are more frequent at night, prevailing at less than 8 miles per hour from 40 to 50 percent of the time (Figure II-2). In the summer, wind speeds are higher than in other seasons during the day and lower during the night.

Temperature inversions usually occur at night and more frequently in the winter when the sky is clear and the wind speed is low. Clear skies allow the earth's surface to radiate and cool at a fast rate, thereby cooling the air near its surface and restricting vertical mixing with the warmer lighter air above it. Low wind speeds also prevent mixing and dispersion of the contaminant. These inversions contribute to

TABLE II-1

PREVAILING DIRECTION AND MEAN HOURLY SPEED OF WIND (mph)
FOR MINNEAPOLIS-ST. PAUL

Jan.	NW	10.6	July	SE	9.5
Feb.	NW	10.9	Aug.	SE	9.4
Mar.	NW	11.6	Sept.	S-SE	10.5
Apr.	NW	12.7	Oct.	SE	10.9
May	SE	11.6	Nov.	NW	11.6
June	SE	11.1	Dec.	NW	10.8

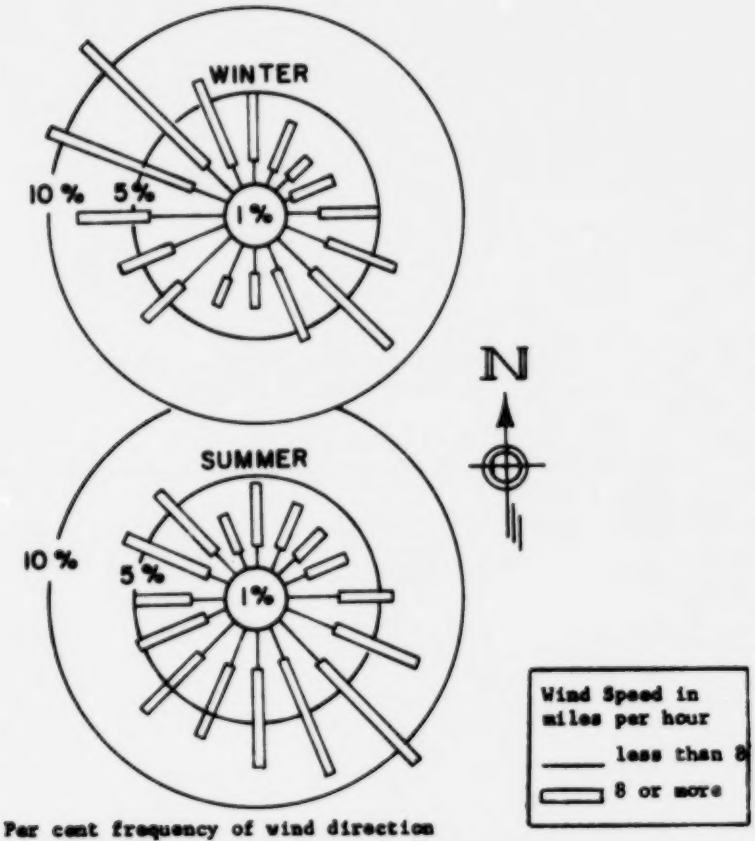

Figure II-1. Per cent frequency of wind direction
Per cent calm given in center circle

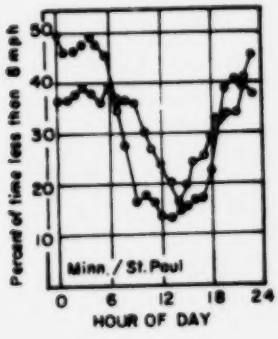

Figure II-2. Hourly Frequency of Wind Speeds Less than Eight Miles Per Hour

the high levels of air pollution around midnight. Carbon monoxide accumulates throughout the heavy traffic on rush hours and the light traffic in the early night hours.

The third condition, condensation, either above as clouds or close to the earth's surface as fog, limits solar heating and decreases the vertical circulation. The presence of fog usually prolongs the inversion making the situation worse. However, heavy fogs usually do not last longer than 24 hours and occur about 10 to 20 times per year.

Meteorological conditions are important not only in the transport and diffusion of carbon monoxide, but also in the rate of formation of photochemical oxidants. As a consequence, two periods of the year require special attention: the fall-winter period for CO and the spring-summer period for photochemical oxidants. In the fall-winter months, when stagnant conditions occur more frequently, maximum CO concentrations may be expected. However, during this period the rate of formation of photochemical oxidants is slow, keeping the concentration low. Photochemical oxidants, which are formed by complex chemical reactions with hydrocarbons and nitrogen oxides, increase as light intensity increases. Thus higher concentrations are higher in the late spring and summer seasons when solar radiation is most intense.

3. Location and Type of Instrumentation

Air quality is monitored at three stations in the Minneapolis-St. Paul area: downtown St. Paul, downtown Minneapolis and at KSTP, a

ratio station which is between the two cities. While CO was measured at all three stations, oxidants were only measured continuously at downtown Minneapolis for the period 1971-1972. The location of each station and the instrumentation for CO and oxidants follows below.

a. Local Station No. 1 - KSTP

A trailer is located about 20 feet from Bedford Street, a side street off the heavily traveled University Avenue. The funneling port above the trailer is well exposed and the air flow is not influenced by nearby structures. Air quality, however, could be influenced by the emptying and filling of the KSTP parking lot and the trucking operations from the Century Trucking platform, which is located about 500 feet away.

During the period from July 1, 1971 to August 15, 1972 a Beckman 315A non-dispersive infrared analyzer with an optical filter was used to monitor the CO. This is the EPA reference method. The data is collected once per minute and is telemetered back to MPCA for reduction. The instrument is well-maintained and the data should be reliable. The data have to be corrected for the 5 ppm offset and the moisture interference. The Beckman correction factor was 1 ppm for a 3.2 mole percent H_2O content.

A Beckman Air Quality Acrylizer was used to measure total oxidants for only the first two months of 1972. Not being adopted by EPA as a reference method, the instrument was discontinued when the pump failed. Presently a McMillan instrument which uses the chemiluminescent dry technique is being installed.

b. Location Station No. 2 - Downtown Minneapolis

The station is located in the Minneapolis Public Health Building on the corner of 4th Street and 3rd Avenue. Air is sampled about 12 feet above the main doorway through one of the metal strips on the side of the building. Being on the side of the building the air flow is restricted to 180°. Streamlines are mainly from the corner of the two streets, whose curbs are about 15 and 30 feet away. Both streets are three or four lanes one way and are frequently traveled especially during the morning and evening commuting time.

A Beckman 315AL non-dispersive infrared CO Analyzer with a desiccant is operated continuously in the laboratory. The instrument is well maintained and the desiccant is changed daily or on alternate days depending on its color. The data are recorded on strip-chart paper, averaged hourly by eyeball and sent to MPCA. This instrument is based on an EPA reference method.

A Beckman Air Quality Acrylizer was used to measure total oxidants for the 1971-72 period. This instrument is not based on an EPA reference method.

c. Local Station No. 3 - Downtown St. Paul

The station is located on the corner of E10th Street and Minnesota Street. A pipe sampler emerges from an old brick building at about 60 feet above a parking lot with a 50-car capacity. The air flow is restricted by the building. Therefore the sampled air comes mostly from the parking lot and the streets whose curbs are about 100 feet away. Both streets are frequently used.

A MSA Lira non-dispersive infrared CO analyzer was used to collect the data at one-minute intervals. Up to August 1972 a method to correct the moisture interference was not used. Recently a refrigerator was installed to eliminate the moisture in the sampling air stream. Since February, 1972, the data were telemetered to MPCA with no correction for offset or for moisture interference. The new system is closely watched and maintained, but the old system without the refrigeration system was not accurate according to the computer programmer and the engineer of the monitoring section. The data, however, can still be utilized to show radiative diurnal and seasonal variations as shown in Figures II-5 and II-6.

4. Review of Air Quality Data

a. General

CO and total oxidant concentrations observed at the three stations during the one-year period from 1 July 1971 through 30 June 1972 have been reviewed and compared. The ozone data from an independent EPA study are presented for support and comparison. In addition seasonal and daily variations for the period have been examined to further define the problem and to provide guidance in developing transportation control strategies.

b. CO Data

One-hour averages of CO were available on computer cards for the Minneapolis and St. Paul stations, making it possible to obtain the 8-hour averages. But the data from KSTP was on books from the teletype output, requiring a thorough search for high data values. When

the one-hour CO concentration exceeded 15.3 ppm, which was the third highest value measured at the Minneapolis station, the associated 8-hour average was calculated.

Table II-2 gives the highest and second highest 1-hour and 8-hour CO concentrations observed during the period from 1 July 1971 through 30 June 1972 and during the year 1970, which was the period used for the state's Implementation Plan. The 1-hour average was highest in 1970 while the 8-hour averages were higher during the July 1, 1971 - June 30, 1972 period. It is interesting to note the excellent agreement between the CO monitors at station KSTP and downtown Minneapolis. For example, the highest CO concentrations occurred on the same day at both stations on November 11, Figures II-3 through II-10 discussed below further illustrate this agreement.

Figures II-3 - 6 compare the diurnal concentration on typical days of each season for the three stations. Data were not available from the St. Paul station for 1971 so only 1972 data are presented. Examination of these data show that the monitors are generally in relative agreement as to the time during which peak concentrations occur. Figure II-4 illustrates this phenomenon especially well.

The period November 10 through November 17 is very important because within this period the highest and second highest one-hour and 8-hour average CO concentration occurred at both the Minneapolis and KSTP monitoring stations. Figure II-8 shows for the first 7 days of this period the one-hour averages for both KSTP and downtown Minneapolis, and

TABLE II-2

HIGHEST AND SECOND HIGHEST CARBON MONOXIDE LEVELS
FOR THE MINNEAPOLIS-ST. PAUL STATIONS

(Values are in Parts per Million by Volume)

	HIGHEST (ppm)		2nd HIGHEST (ppm)	
DATA SOURCE	1 Hour (Date)	8 Hour (Date)	1 Hour (Date)	8 Hour (Date)
Station #1 - KSTP (July '71 - June '72)	35.8 (11-11-71)	26.2 (11-11-71)	27.2 (11-15-71)	21.6 (11-15-71)
Station #2 - MPLS (July '71 - June '72)	33.0 (11-10-71)	18.9 (11-11-71)	29.0 (9-22-71) 29.0 (11-17-71)	17.5 (11-10-71)
Station #3 - St. Paul (Jan. '71 - June '72)	17.5 (1-18-72)	*	14.0 (2-10-72)	*
Station #2 - MPLS (Jan '70 - Dec. '70)	44.6**	17.1**		
Used in Implementation Plan				

* Not calculated from one-hour averages because of inaccuracies in data.

**Values used in Implementation Plan.

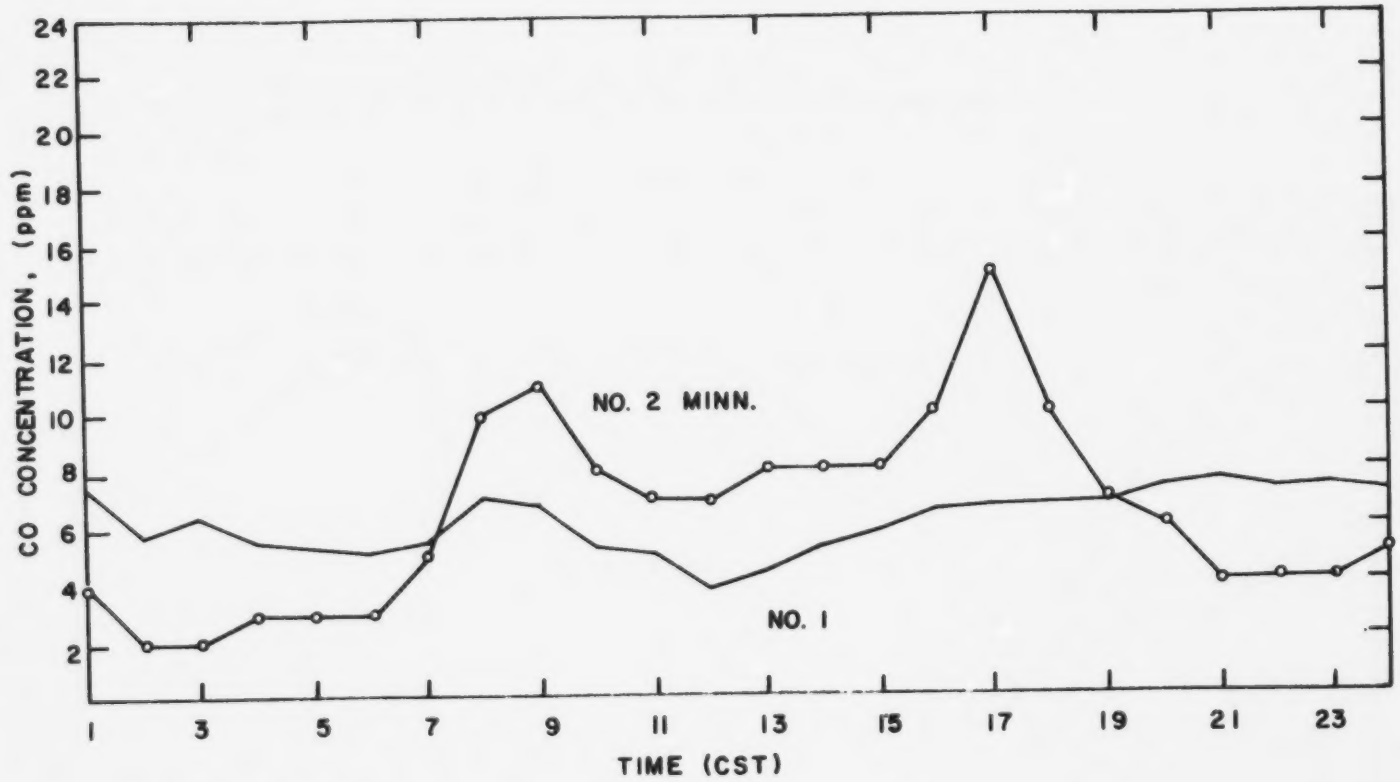

Figure II-3. Diurnal Variation in Average 1-hour Carbon Monoxide Concentration at KSTP and Minneapolis - Aug. 16 - Summer 1971

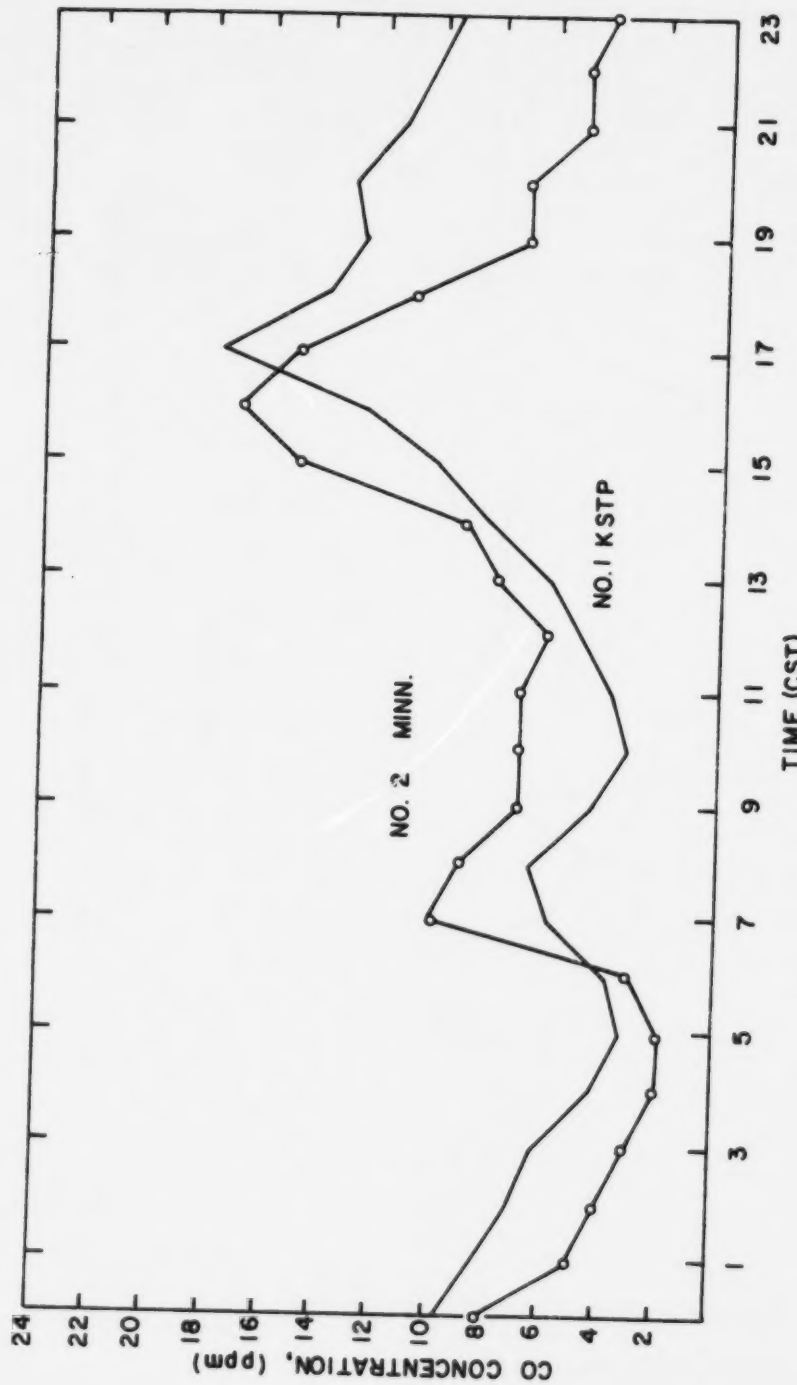

Figure II-4. Diurnal Variation in Average 1-hour Carbon Monoxide Concentration at KSTP and Minneapolis - Nov. 12 - Fall 1972

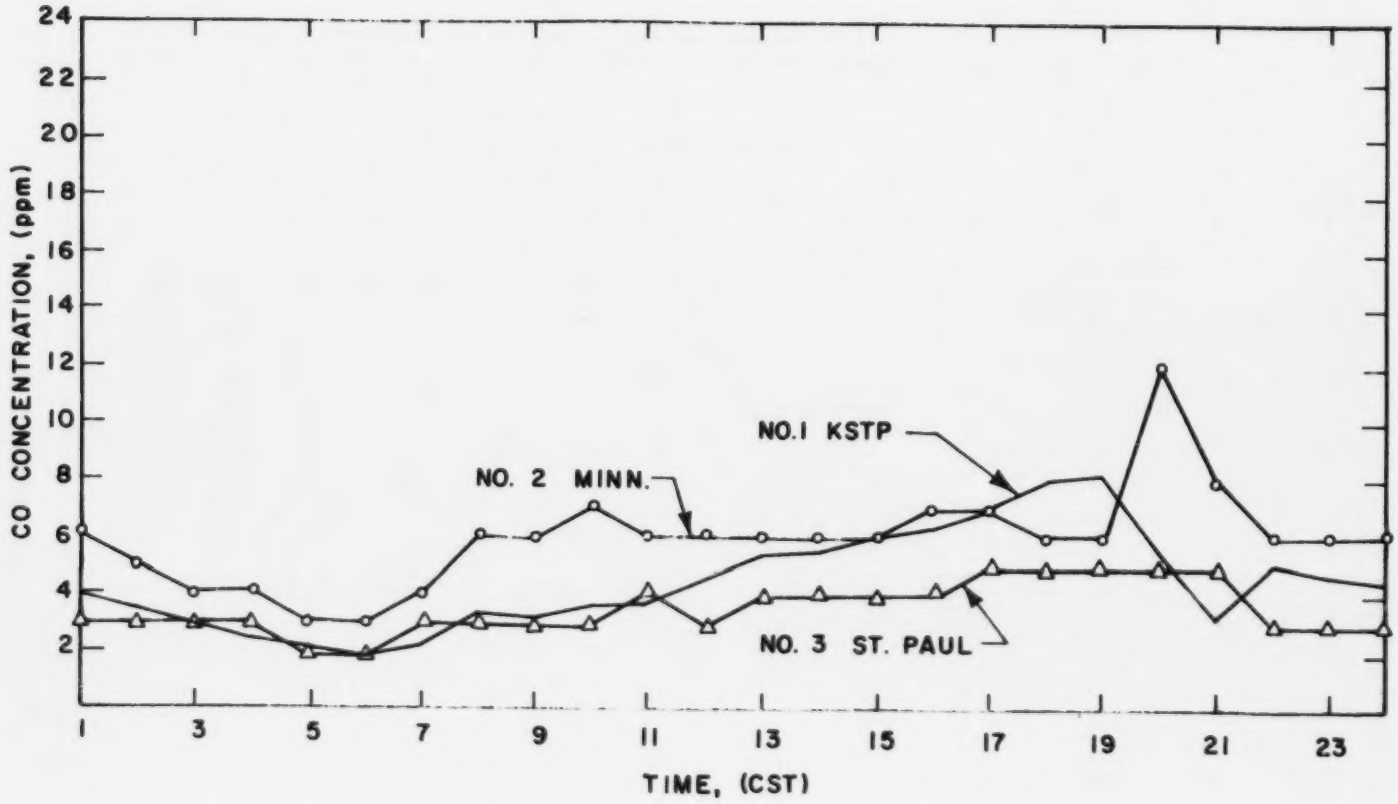

Figure II-5. Diurnal Variation in Average 1-hour Carbon Monoxide Concentration at KSTP, Minneapolis, and St. Paul - Feb. 12 - Winter 1972

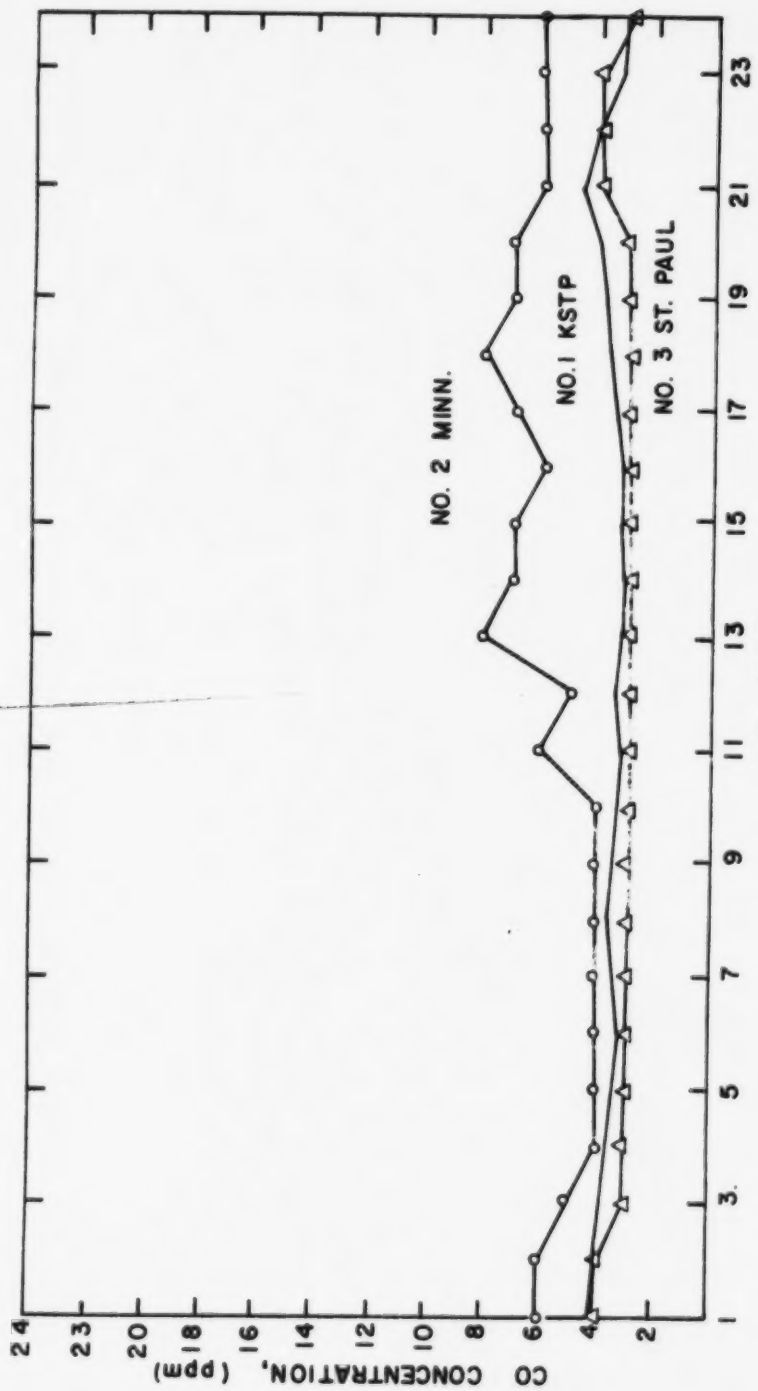

Figure II-6. Diurnal Variation in Average 1-hour Carbon Monoxide Concentration at KSTP, Minneapolis and St. Paul - May 14 - Spring 1972

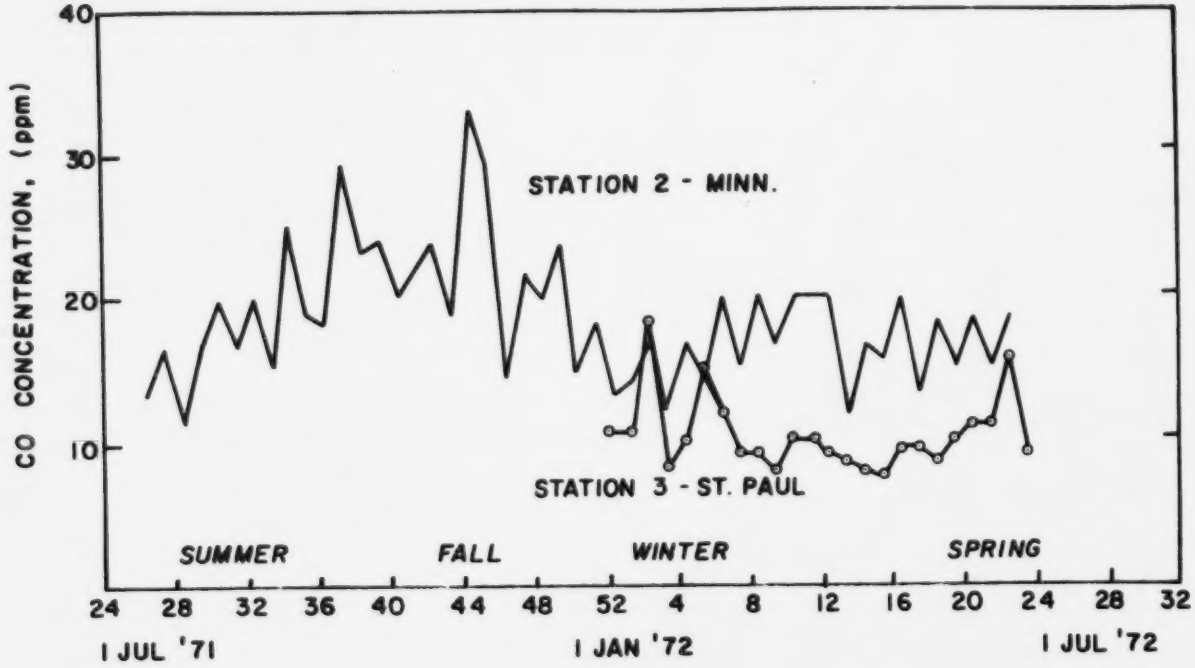

Figure II-7. Seasonal Weekly Maximum 1-hour Carbon Monoxide Concentration at Minneapolis and St. Paul

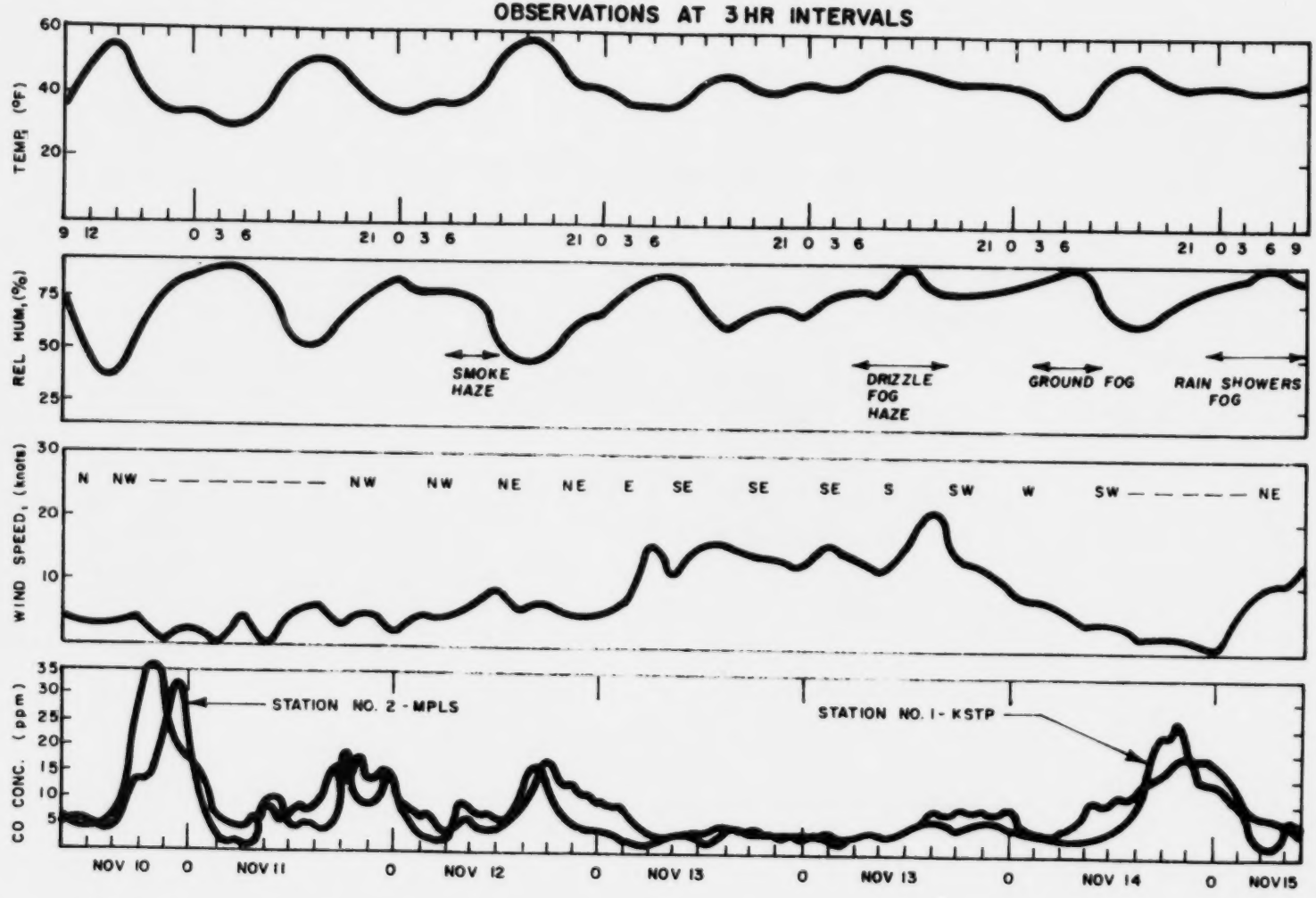

Figure II-8. **Diurnal Variation of Average 1-hour CO Concentration with Meteorological Conditions During the Highest and Second Highest Peaks.**

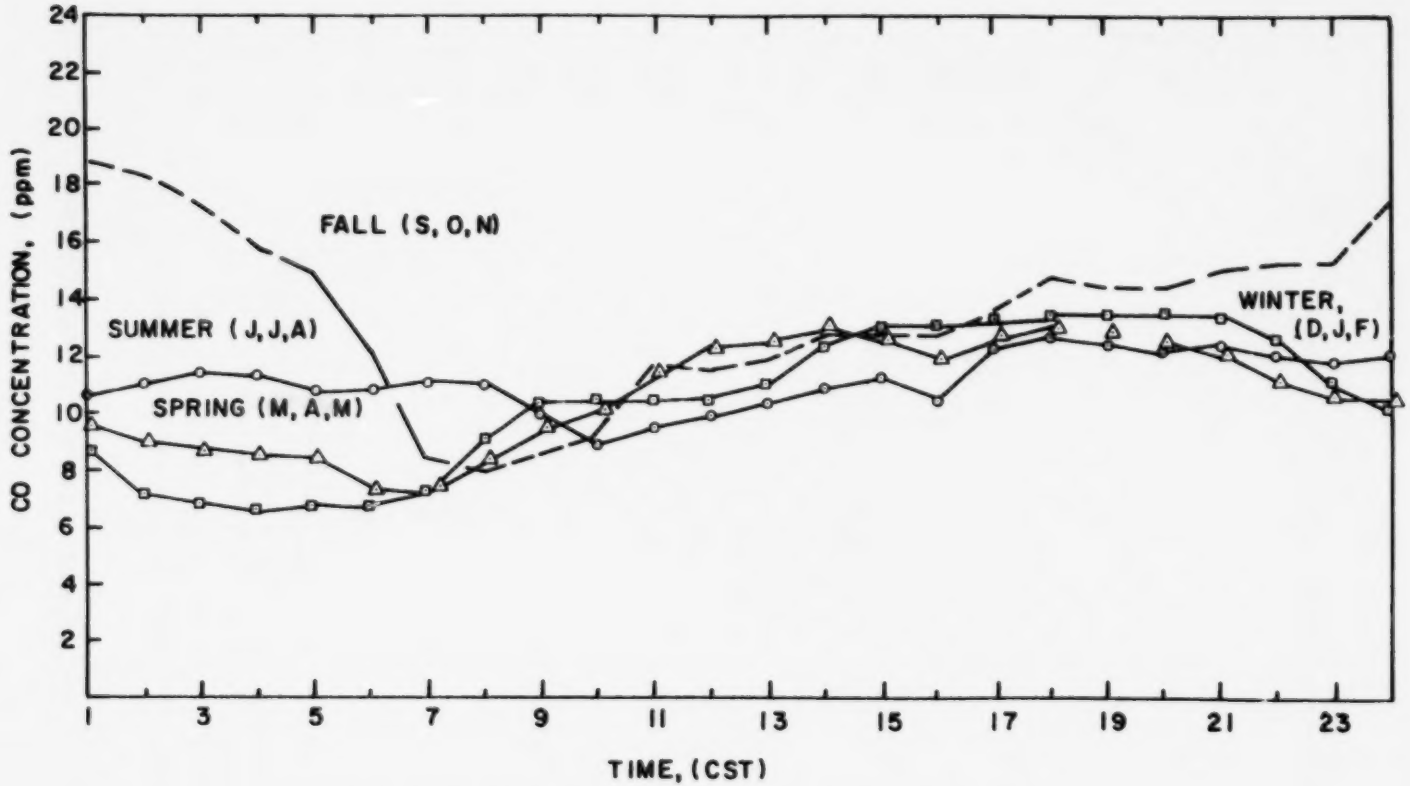

Figure II-9. Diurnal Variation of the Maximum 8-hour Carbon Monoxide Concentration at Station 8 - Minneapolis (July '71 - June '72)

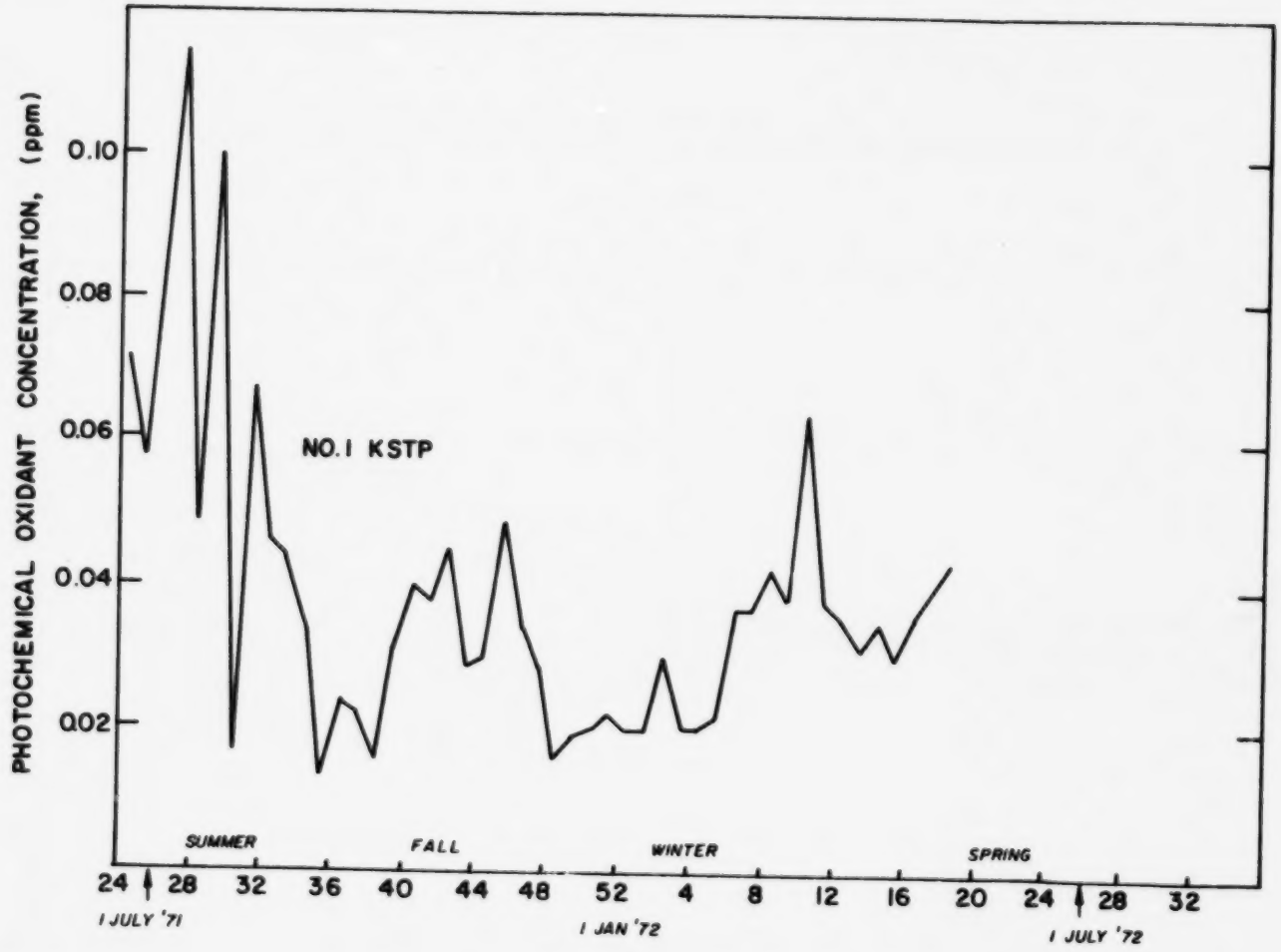

Figure II-10. Weekly 1-hour Maximum Total Oxidant Concentration at Minneapolis.

the meteorological conditions of temperature, relative humidity and wind speed and direction. These data were obtained from the climatological summaries measured at the Minneapolis -St. Paul Airport. The CO concentration pattern for the two stations is very similar. The concentration fluctuates more at downtown Minneapolis and it usually peaks during the commuting hours. The pattern is highly influenced by the weather as will be discussed below.

During the time period in Figure II-8, the effects of the three conditions that severely influence the level of air pollution can be seen. The high peaks occur when there is no wind. The average CO concentration was less than 7 ppm when the wind was blowing over 10 mph. The first and highest peak of the period was caused by low wind speeds and a temperature inversion during the night. The second and third peaks occurred during early night when the wind speed prevailed at less than 6 mph, and temperatures decreased considerably. The second highest peak occurred around 9:00 PM on November 15 when fog was present, light winds prevailed, and temperatures decreased. Because of poor mixing, the evening and early night vehicle emissions accumulated over the area causing the high CO level.

Figure II-9 presents a summary of the diurnal variation of maximum 8-hour CO concentrations in downtown Minneapolis for each of the four seasons from July 1971 through June 1972. The diurnal pattern is similar in all seasons except for the fall's amplitude during the night. This significant difference can be misleading because these large

8-hour concentrations only occurred a few times in the fall, specifically from 10:00 PM to 6:00 AM. The concentration falls from about midnight to six o'clock in the morning, rises during the day when vehicle activity increases and persists through the night only with poor dispersion conditions. A higher rise is observable during the commuting hours.

Several other conclusions about the diurnal and seasonal variation can be obtained from Table II-3, which gives the highest 8-hour concentration observed during each hour of the day for each month. The federal standard of 9 ppm is frequently exceeded from the afternoon to midnight. The number of times the standard is exceeded increases from 1 at 7:00 AM to a maximum of 76 at 6:00 PM, and decreases thereafter. During the fall-winter months, especially in October, the standard is frequently exceeded.

c. Total Oxidant Data

Total oxidant data were generated only from downtown Minneapolis and summary data from this station were available as average daily and maximum one-hour concentrations. Figure II-11 is a plot of the weekly maximum one-hour oxidant concentration. Although the variance is high, because sky cover varied, the higher total oxidants concentrations happen in the spring and summer months when solar radiation is most intense. The standard of .08 ppm was exceeded just a few times during the year; specifically July 5-20, 1971.

A special study of ozone levels in the Minneapolis -St. Paul area was carried out by EPA in conjunction with state and local

TABLE II-3

MAXIMUM 8-HR. CO CONCENTRATION (PPM) AND THE NUMBER OF TIMES THE STANDARD WAS EXCEEDED IN MINNEAPOLIS DURING THE PERIOD 1 JULY 1971 to 31 JULY 1972

(Entry is at hour ending 8-hour period)

HOUR	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	MAX	NO. OF TIMES OVER STANDARD
01	8	8	11 (1)	10 (2)	19 (3)	7	7	9	10 (2)	7	9	11 (1)	18.9	(9)
02	8	7	10 (1)	9 (1)	19 (3)	6	5	7	9	7	9	11 (1)	18.5	(6)
03	7	7	9 (1)	8	17 (2)	6	5	7	8	6	9	11 (1)	17.4	(4)
04	7	7	9	7	16 (2)	6	5	7	7	6	9	11 (1)	15.8	(3)
05	7	8	8	7	15 (2)	6	4	7	6	6	8	11 (1)	14.9	(3)
06	6	7	8	7	12 (1)	7	5	7	6	6	7	11 (1)	12.4	(2)
07	6	6	8	7	8	7	5	7	6	7	8	11 (1)	11.1	(1)
08	6	6	8	7	6	7	6	9 (1)	7	8	8	11 (1)	11.0	(2)
09	7	6	8	8	7	8	8	10 (1)	7	10 (1)	8	10 (2)	10.1	(4)
10	7	7	8	9 (1)	7	8	8	10 (2)	8	10 (1)	9	9 (1)	10.5	(5)
11	8	7	8	12 (2)	8	9	9 (1)	10 (2)	8	11 (1)	10 (1)	10 (2)	11.8	(9)
12	8	8	9	12 (2)	8	10 (2)	10 (1)	11 (3)	9	12 (2)	10 (1)	10 (5)	12.4	(16)
13	9	9 (1)	9 (1)	12 (6)	8	11 (3)	11 (1)	11 (3)	10 (1)	13 (2)	11 (1)	12 (6)	13.0	(25)
14	10 (4)	10 (1)	10 (2)	13 (7)	10 (2)	13 (4)	11 (4)	12 (4)	11 (5)	13 (5)	12 (1)	14 (6)	13.7	(45)
15	10 (5)	10 (1)	10 (3)	13 (10)	11 (4)	13 (6)	10 (5)	12 (4)	11 (6)	13 (5)	12 (1)	14 (7)	13.6	(57)
16	11 (7)	10 (2)	10 (2)	13 (9)	12 (6)	13 (5)	10 (4)	11 (3)	12 (6)	12 (3)	12 (1)	14 (5)	13.7	(51)
17	12 (7)	11 (5)	11 (4)	14 (12)	12 (6)	13 (8)	10 (4)	11 (2)	12 (8)	13 (3)	12 (1)	14 (9)	14.0	(69)
18	12 (8)	11 (9)	13 (4)	15 (12)	14 (8)	13 (8)	10 (3)	11 (3)	12 (8)	13 (3)	12 (1)	13 (9)	14.8	(76)
19	12 (7)	11 (6)	13 (5)	15 (12)	14 (7)	13 (7)	10 (1)	10 (3)	13 (8)	13 (3)	12 (3)	13 (8)	14.5	(70)
20	12 (6)	11 (5)	12 (4)	14 (13)	14 (7)	13 (7)	9 (1)	11 (2)	12 (8)	12 (2)	12 (3)	13 (9)	14.4	(67)
21	11 (6)	10 (5)	12 (5)	14 (12)	15 (7)	13 (2)	9	11 (2)	12 (7)	12 (1)	12 (2)	12 (9)	15.0	(58)
22	11 (4)	10 (4)	13 (4)	13 (11)	15 (7)	13 (2)	8	11 (2)	11 (6)	11 (1)	11 (2)	12 (4)	15.3	(47)
23	10 (2)	10 (3)	13 (2)	13 (10)	15 (6)	11 (2)	8	11 (2)	10 (1)	11 (1)	11 (1)	12 (3)	15.3	(33)
24	9 (1)	9 (1)	13 (1)	11 (8)	18 (4)	9 (1)	8	10 (2)	11 (1)	9 (1)	10 (1)	12 (2)	17.5	(23)
MAX	12.0	11.1	13.1	14.8	18.9	13.4	10.6	11.6	12.6	13.0	12.4	13.7	18.9	
NO. TIMES STD. EXCEEDED	(57)	(43)	(48)	(130)	(75)	(58)	(25)	(41)	(70)	(35)	(20)	(96)		

* NO. TIMES STANDARD EXCEEDED WAS NOT CALCULATED

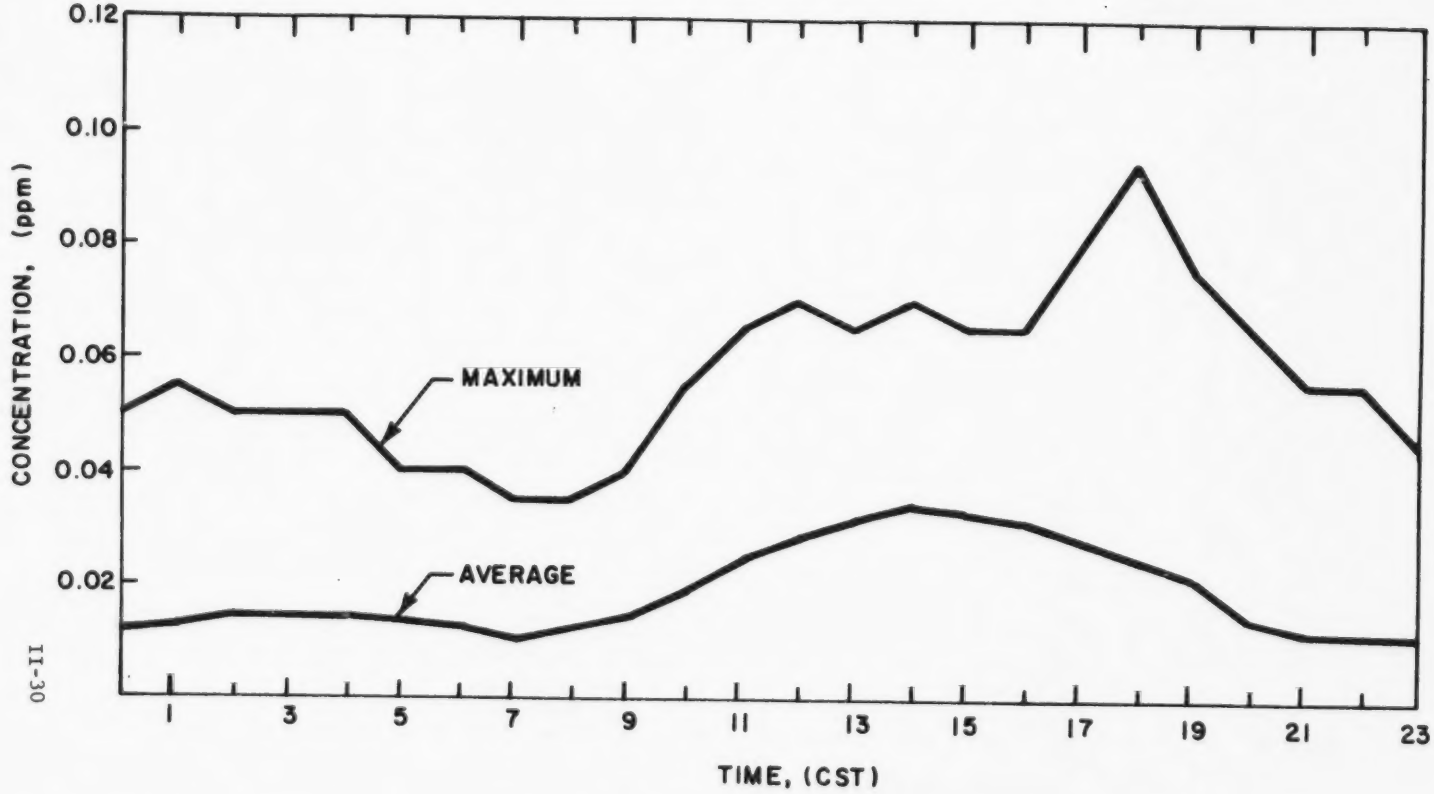

Figure II-11. Diurnal Variation of the Maximum and Average 1-hour Ozone Concentration for July - Sept. 1971 at KSTP Station, by EPA.

agencies for the months of July through September 1971. Using the reference method in the Federal Register, Vol. 26, No. 84, April 30, 1971, a chemiluminescent dry technique, ambient ozone concentrations were measured continuously at the KSTP monitoring site. The data showed that the standard was exceeded only once at 0.095 ppm. This agrees with the few times exceeded by the (total oxidant) wet technique, which normally gives slightly higher readings. Figure II-11 plots the maximum and average 1-hour diurnal variation for the three months during which the EPA study was conducted. Both curves have higher concentrations when solar radiation is intense.

Table II-4 lists the highest and second highest oxidant levels observed from the EPA study, and from the data generated at the Minneapolis station. The first and second highest data points measured in downtown Minneapolis are believed to be high because the instrument was shut down several times in July 1971.

TABLE II-4

HIGHEST OXIDANT LEVELS OBSERVED AT MINNEAPOLIS

Sampling Source and Period	1-H_y Concentrations (ppm)	
Station #2 - MPLS (July 1971 - June 1972)	.114 Total oxidant	.100 Total Oxidant
EPA Study Station No. 1 KSTP (July 1971 - Sept. 1971)	0.095 Ozone	.080 Ozone

5. Present and Projected Non-Vehicular Source Emissions in AQCR 131

Tables II-5 through II-8 present 1970 non-vehicular CO and hydrocarbon emissions in Region 131 and Hennepin and Ramsey counties, the two most populous counties in the region. These tables were developed from the Emissions Inventory in the state of Minnesota's Implementation Plan. Growth factors for each source category were also obtained from the Implementation Plan and used to project emissions for both 1971 and 1977. The projected emissions for these years are also presented in these tables.

C. DISCUSSION OF 1971 and 1977 VMT DATA

Basic data were provided by a number of cooperating agencies, particularly: the Traffic Bureau of Department of Public Works, City of St. Paul; the Traffic Division, Public Works Department, City of Minneapolis; the Twin Cities Area Transportation Program and its participants (Metropolitan Council, Minnesota Highway Department, Metropolitan Transit Commission and the Metropolitan Counties and Municipalities).

Specifically, the following comprise the key items used to estimate the present vehicle miles of travel (VMT) and to project these traval magnitudes to the study period:

(a) Vehicle Traffic Flow Map, City of Minneapolis, 1970 Average Daily Traffic.

(b) Traffic Volume Flow Map, City of St. Paul, 1969-1971.

(c) Travel Behavior Inventory, Twin Cities Area.

TABLE II-5

REGION 131 CO EMISSIONS FROM NON-MOTOR VEHICLE SOURCES

Sources	1970 CO Emissions (Tons/yr)	Growth Factors (1971) X	(1977) X^7	Projected CO Emissions Assuming that no control strategies Applied 1971	(tons) 1977
Fuel Combustion					
Residential	1,895	1.0176	1.130	1,920	2,140
Commercial & Institutional	650	1.054	1.445	685	940
Industrial	108	1.039	1.309	112	141
Power Plants	1,940	1.039	1.309	2,020	2,540
Process Losses	9,600	1.028	1.213	9,860	11,600
Solid Waste Disposal	16,027	1.018	1.133	16,300	18,200
Railroads	1,500	1.021	1.157	1,530	1,730
Aircraft	55,500	1.042	1.334	57,900	74,000
Total (tons/yr)	87,220			90,327	111,291

TABLE II-6

REGION 131 HYDROCARBON EMISSIONS FROM NON-MOTOR VEHICLE SOURCES

Sources	1970 HC Emissions (tons/yr)	Growth Factors 1971 X	Growth Factors 1977 X^7	Projected Hydrocarbon Emissions Assuming that no Control Strategies Applied (tons) 1971	1977
Fuel Combustion					
Residential	670	1.076	1.130	720	757
Commercial & Institutional	300	1.054	1.445	316	434
Industrial	1,470	1.039	1.309	1,530	1,920
Power Plants	3,060	1.039	1.309	3,180	4,000
Process Losses	25,250	1.028	1.213	26,000	30,600
Solid Waste Disposal	5,300	1.018	1.133	5,390	6,010
Railroads	1,150	1.021	1.157	1,175	1,330
Aircraft	13,000	1.042	1.334	13,580	17,360
Handling	9,300	1.035	1.272	9,630	11,850
Evaporative Losses	22,500	1.018	1.133	22,900	25,000
Total (tons/yr)	82,000			84,421	99,261

TABLE II-7

CO EMISSIONS FROM NON-MOTOR VEHICLE SOURCES FOR HENNEPIN AND RAMSEY COUNTIES

Sources	1970 CO Emissions (Tons/yr)	Growth Factors (1971) X	(1977) X^7	Projected CO Emissions Assuming that no control strategies Applied (tons) 1971	1977
Fuel Combustion					
Residential	1,276	1.0176	1.130	1,373	1,442
Commercial & Institutional	453	1.054	1.445	477	655
Industrial	41	1.039	1.309	43	54
Power Plants	1,632	1.039	1.309	1,696	2,136
Process Losses	9.384	1.028	1.213	9,647	11,383
Solid Waste Disposal	10,212	1.018	1.133	10,396	11,570
Railroads	640	1.021	1.157	653	740
Aircraft	50,542	1.042	1.334	52,665	67,423
Total (tors/yr)	74,180			76,950	95,403

TABLE II-8

HYDROCARBON EMISSIONS FROM NON-MOTOR VEHICLE SOURCES FROM HENNEPIN AND RAMSEY COUNTIES

Sources	1970 HC Emissions (tons/yr)	Growth Factors 1971 X	Growth Factors 1977 X^7	Projected Hydrocarbon Emissions Assuming that no Control Strategies Applied (tons) 1971	Projected Hydrocarbon Emissions Assuming that no Control Strategies Applied (tons) 1977
Fuel Combustion					
Residential	461	1.076	1.130	496	521
Commercial & Institutional	197	1.054	1.445	208	285
Industrial	966	1.039	1.309	1,004	1,264
Power Plants	2,879	1.039	1.309	2,991	3,769
Process Losses	25,236	1.028	1.213	25,943	30,611
Solid Waste Disposal	3,217	1.018	1.133	3,275	3,645
Railroads	517	1.021	1.157	528	598
Aircraft	11,910	1.042	1.334	12,410	15,888
Handling	6,195	1.035	1.272	6,412	7,880
Evaporative Losses	18,270	1.018	1.133	18,599	20,700
Total (tons/yr)	69,848			71,866	85,161

(d) Registration Data on Motor Vehicles.

(e) Vehicular Traffic Flow in Central Business District, Average One Hour in 1969, City of Minneapolis.

(f) Travel Speed Data.

1. Estimation of VMT in 1970

The methodology employed in estimating 1970 average daily travel (ADT) for the Central Business Districts of Minneapolis and St. Paul, as well as those for the Urban Activity Districts in the remaining areas of the Twin Cities involved the use of the traffic volume maps. Basic differences in data caused slight variances in methods of calculation required.

a. Minneapolis CBD

Traffic data available for this district related flow magnitudes on city streets as the average one-hour volumes of the 12-hour period between 6:30am to 6:30pm in 1969. These street volumes were converted to Vehicle-miles by multiplying by distances between intersections on the map. The average hourly vehicle-miles thus obtained was expanded to 24-hour values by multiplying by the factor 15.9, which was derived by the Traffic Division.

b. St. Paul-CBD

Traffic flow data available for this area were in terms of ADT volumes for major facilities determined over a period from 1969 through 1971. On the assumption that these data would average to conditions in 1970, volumes on each link were multiplied by link distance to obtain

24-hour VMT values. The sum of all link VMT's then corresponded to the total VMT generated in the CBD.

c. Municipal Urban Activity Districts

Traffic volume maps for the cities of Minneapolis and St. Paul are presented in Figures II-12 and II-13. Overlays of the standard planning areas (CBD's) were used in conjunction with these maps. Linkages on these maps were categorized as "Freeway/Interstate" and other. The latter category of linkages were divided in "Principal Arterials" if ADT exceeded 5000 and to "Secondary Streets" for facilities less than this volume. Linkage distances were scaled from maps and used to convert ADT to 24-hour VMT by these three categories.

d. Conversion of 24-hour VMT to 12-hour VMT

A conversion factor was derived for this purpose using expansion factors developed by the Minneapolis Traffic Division for CBD traffic. Two factors were used. The factor for converting average hourly volumes to 12-hour volumes was "12", while that used to convert hourly average to 24-hour volumes was "15.9". Thus the conversion factor to convert all 24-hour VMT volumes to 12-hour VMT volumes was:

$$\frac{12}{15.9} = 0.75$$

2 Estimating 1971 and 1977 Travel

The 1970 VMT estimates were expanded using information on person-trip data and forecasts contained in the travel behavior inventory generated

Figure II-12. Vehicular traffic flow for city of Minneapolis.

Reproduced from best available copy.

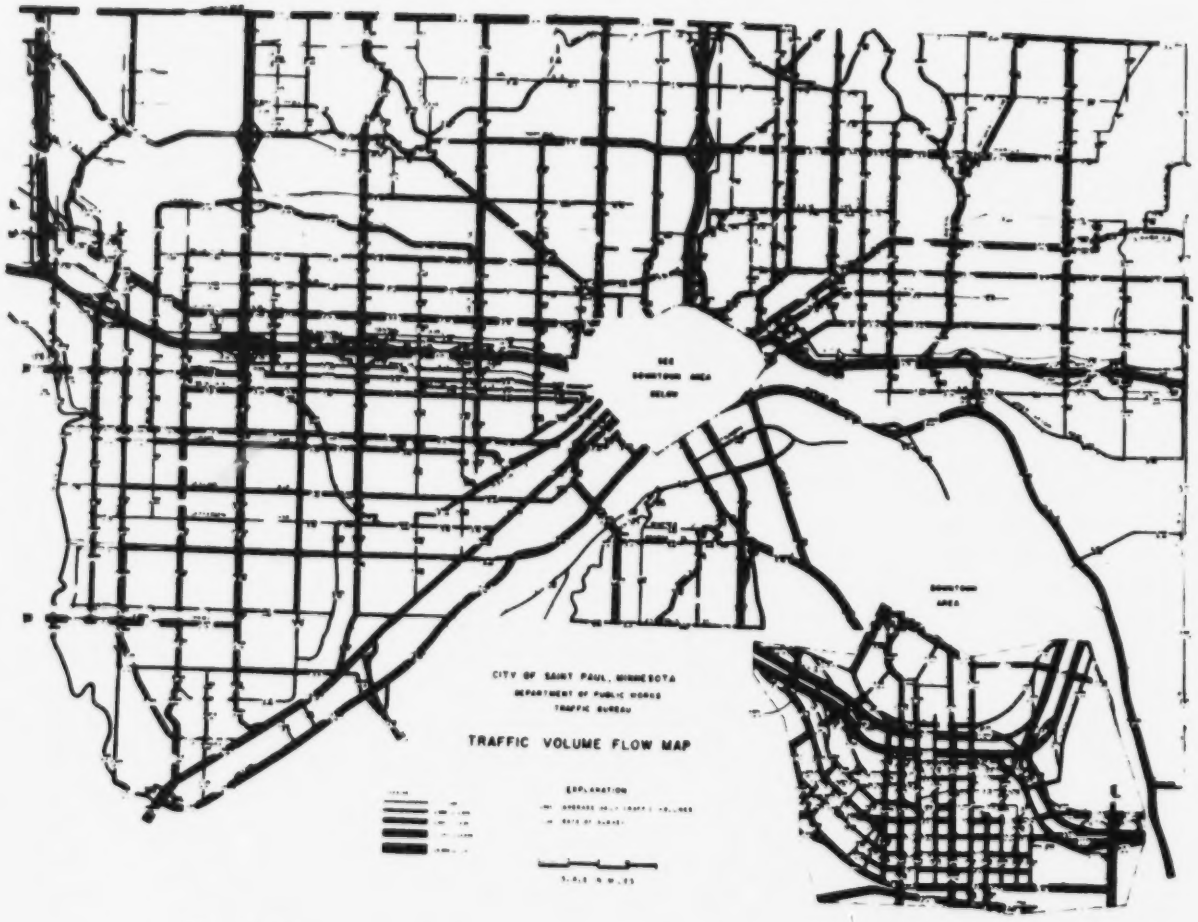

Figure II-13. Vehicular traffic flow for city of St. Paul.

in the Twin Cities Area Transportation Program. The following data was obtained:

Person-trips (1970) = 5,095,000

Person-trips (1980) = 6,725,000

10-year travel growth = $\frac{6,725,000}{5,095,000}$ = 1.32

The linear annual growth rate is therefore:

Rate = $\frac{0.32}{10}$ or 3.2% per year.

Therefore, to expand 1970 base year data, the following relationships are used:

VMT Base Data (1970) X 1.032 = VMT (1971)

VMT Base Data (1970) X 1.224 = VMT (1977)

3. Vehicle Type

The average vehicle mix in the traffic stream was based upon information from the respective traffic divisions as follows:

	Minneapolis (%)	St. Paul (%)
Light Duty (includes auto, taxis, and light trucks)	92.5	90.0
Heavy Duty (includes medium and heavy trucks)	6.0	8.5
Other (includes buses)	1.5	1.5
TOTAL	100.0	100.0

4. Estimation of Traffic Density

To obtain traffic density in VMT per square mile, the area of each urban activity district and the CBD's was obtained by scaled measurement using a planimeter. The area of each district was divided into the VMT volume by type of acility. The resultant densities are shown in Tables II-9 through II-11.

5. Speed

Speeds of travel on streets and freeways were estimated from data and information obtained from the respective city traffic organizations as follows:

		Average Speed (mph)		
		Freeways/ Interstates	Principal Arterials	Secondary Streets
MINNEAPOLIS				
	CBD	N.A.	14	N.A.
UAD	52	N.A.	35	25
UAD	53	N.A.	35	25
UAD	54	50	35	25
UAD	55	45	30	23
UAD	56	45	30	23
UAD	63	40	30	23
UAD	64	43	35	25
UAD	65	45	35	25
UAD	66	50	35	25
UAD	67	50	35	25
UAD	68	55	35	25
UAD	69	55	35	25
ST. PAUL				
	CBD	35	12	N.A.
UAD	79	50	35	25
UAD	80	48	35	25
UAD	81	48	35	25
UAD	82	48	35	25
UAD	83	40	30	23
UAD	89	40	30	23
UAD	90	48	35	25
UAD	91	50	35	25
UAD	92	45	35	25
UAD	93	N.A.	35	25

TABLE II-9

TRAFFIC DENSITY

FREEWAY/INTERSTATE

Urban Activity District	Area Square Miles	1970 VMT (24 hrs)	1971 VMT (24 hrs)	1971 VMT Per Sq. Mile (24 hrs)	1977 VMT (24 hrs)	1977 VMT Per Sq. Mile (24 hrs)
MINNEAPOLIS						
57-62(CBD)	2.2	0	0	0	0	0
52	5.28	0	0	0	0	0
53	8.60	0	0	0	0	0
54	5.04	118,900	122,705	24,100	145,530	28,880
55	5.48	49,950	51,552	9,408	61,140	11,160
56	5.96	190,990	197,098	33,074	233,770	39,220
63	1.40	113,520	117,157	83,685	138,950	99,250
64	5.56	224.700	231,812	41,697	275,000	49,460
65	5.60	94,600	97,623	17,430	115,790	20,680
66	5.20	103,900	107,225	20,621	127,180	24,460
67	4.08	103,960	107,283	26,295	127,250	31,190
68	2.60	90,900	93,811	36,081	111,260	42,790
69	6.20	90,900	93,811	15,131	111,260	17,950
ST. PAUL						
84-88 (CBD)	0.8	27,500	28,300	35,400	33,600	41,900
79	6.00	90,300	93,190	15,528	110,530	18,420
80	3.12	71,040	73,317	23,501	86,950	27,870
81	6.60	53,280	54,985	8,332	65,220	9,880
82	3.20	166,800	172,142	53,792	204,160	63,800
83	6.88	196,650	202,947	29,495	240,700	34,990
89	3.84	79,800	82,347	21,445	97,680	25,440
90	13.48	87,075	89,864	6,663	106,580	7,910
91	4.48	73,500	75,848	16,935	89,960	20,080
92	7.28	7,350	7,585	1,038	9,000	1,240
93	3.80	0	0	0	0	0

TABLE II -10

TRAFFIC DENSITY

PRINCIPAL ARTERIAL

Urban Activity District	Area Square Miles	1970 VMT (24 hrs)	1971 VMT (24 hrs)	1971 VMT Per Sq. Mile (24 hrs)	1977 VMT (24 hrs)	1977 VMT Per Sq. Mile (24 hrs)
MINNEAPOLIS						
57-62(CBD)	2.2	377,000	390,000	177,000	463,000	210,000
52	5.28	134,740	139,048	26,333	164,920	31,240
53	8.60	367,560	379,318	44,102	449,890	52,310
54	5.04	224,610	231,802	45,994	274,920	54,550
55	5.48	351,020	362,248	66,100	429,650	78,400
56	5.96	284,770	293,878	49,311	348,560	58,320
63	1.40	57,200	59,030	42,163	70,020	50,010
64	5.56	385,170	397,495	71,493	471,450	84,790
65	5.60	188,850	194,897	34,801	231,150	41,280
66	5.20	120,580	124,441	23,928	147,590	28,380
67	4.08	124,220	128,195	31,426	152,050	37,270
68	2.60	148,880	153,646	59,098	182,230	70,090
69	6.20	179,470	185,207	29,874	219,670	35,430
ST. PAUL						
84-88(CBD)	0.8	110,000	113,000	142,000	135,000	168,000
79	6.00	189,000	195,042	32,512	231,330	38,550
80	3.12	84,340	87,041	27,895	103,230	33,090
81	6.60	161,540	166,711	25,257	197,730	29,960
82	3.20	156,520	161,531	50,475	191,580	59,870
83	6.88	309,000	318,882	46,353	378,210	54,970
89	3.84	67,120	69,262	18,041	82,150	21,390
90	13.48	188,760	194,800	14,452	231,040	17,140
91	4.48	161,850	167,031	37,284	188,100	41,990
92	7.28	216,390	223,315	30,679	264,860	36,380
93	3.80	119,990	123,830	32,589	146,870	38,650

TABLE II-11

TRAFFIC DENSITY

SECONDARY STREETS
(<5,000 ADT)

Urban Activity District	Area Square Miles	1970 VMT (24 hrs)	1971 VMT (24 hrs)	1971 VMT Per Sq. Mile (24 hrs)	1977 VMT (24 hrs)	1977 VMT Per Sq. Mile (24 hrs)
MINNEAPOLIS						
57-62(CBD)	2.2	0	0	0	0	0
52	5.28	29,160	30,093	5,703	35,690	6,760
53	8.60	14,710	15,180	1,765	18,010	2,090
54	5.04	7,650	7,895	1,571	9,360	1,860
55	5.48	9,810	10,116	1,843	12,000	2,190
56	5.96	30,760	31,746	5,325	37,650	6,320
63	1.40	6,400	6,605	4,714	7,830	5,590
64	5.56	32,630	33,676	6,062	39,940	7,180
65	5.60	44,810	46,246	8,254	54,850	9,800
66	5.20	45,120	46,566	8,952	55,230	10,620
67	4.08	12,980	13,395	3,288	15,890	3,900
68	2.60	7,240	7,468	2,871	8,860	3,410
69	6.20	29,750	30,698	4,956	36,410	5,870
ST. PAUL						
84-88 (CBD)	0.8	0	0	0	0	0
79	6.00	27,200	28,070	4,675	33,290	5,550
80	3.12	16,640	17,168	5,499	20,370	6,530
81	6.60	55,190	56,954	8,632	67,550	10,240
82	3.20	25,970	26,799	8,370	31,790	9,930
83	6.88	68,910	71,115	10,339	84,350	12,260
89	3.84	1,770	1,823	475	2,170	570
90	13.48	28,430	29,340	2,173	34,800	2,580
91	4.48	29,630	30,572	6,828	36,260	8,090
92	7.28	31,280	32,279	4,432	38,280	5,260
93	3.80	30,710	31,687	8,341	37,590	9,890

D. ESTIMATION OF 1977 AIR QUALITY DATA

1. 1971 and 1977 Emission Densities of CO and Hydrocarbons in Minneapolis and St. Paul Metropolitan Areas

Tables II-12 and II-13 indicate the emission densities of carbon monoxide and hydrocarbons in the Minneapolis and St. Paul CBD's as well as the other 22 Urban Activity Districts (UAD) comprising the Minneapolis and St. Paul metropolitan areas. These emission densities were developed for the years 1971 and 1977 and include emissions from non-vehicular as well as vehicular sources. The 1977 emission estimates were based on projected growth of both the vehicular and non-vehicular sources as well as the effect of the Federal Motor Vehicle Emission Control Program on automotive emissions.

a. Non-Vehicular Sources of Emissions

Tables II-7 and II-8 present the non-vehicular emissions estimates of carbon monoxide and hydrocarbons in Ramsey and Hennepin counties for the years 1971 and 1977. The following procedures were followed to estimate non-vehicular emissions in the CBD's and UAD's as presented in Tables II -12 and II-13.

- Hennepin and Ramsey county CO and Hc emission totals were apportioned to the Metropolitan areas by population.
- These metropolitan totals were then apportioned to the various UAD's by geographic area
- Emissions from solid waste disposal (open burning) were not included because existing regulations now prohibit such a practice.

TABLE II -12

SUMMARY OF CO EMISSION INFORMATION WITH NO CONTROL STRATEGIES APPLIED FOR METROPOLITAN AREAS OF MINNEAPOLIS AND ST. PAUL

Location	Square Miles	CO Emission Density (kgm/sq mile/12 hrs) 1971 Vehicles	1971 Other	1971 Total	1977 Vehicles	1977 Other	1977 Total	1978 Vehicles	1978 Other	1978 Total	1979 Vehicles	1979 Other	1979 Total
Minn. Metrop. Area; Urban Activity Dist.													
57-62 (CBD)	2.20	12,713	109	12,822	6,442	129	6,571	5,433	131	5,564	4,560	133	4,693
52	5.28	1,156	109	1,265	613	129	742						
53	8.60	1,588	109	1,647	844	129	973						
54	5.04	2,252	109	2,361	1,228	129	1,357						
55	5.48	2,823	109	2,932	1,495	129	1,624						
56	5.96	3,007	109	3,116	1,606	129	1,735						
63	1.40	4,373	109	4,482	2,342	129	2,471						
64	5.56	3,900	109	4,009	2,097	129	2,226						
65	5.60	2,035	109	2,144	1,089	129	1,218						
66	5.20	1,742	109	1,851	937	129	1,066						
67	4.08	1,883	109	1,992	1,020	129	1,149						
68	2.60	2,982	109	3,091	1,620	129	1,749						
69	6.20	1,594	109	1,703	860	129	989						
KSTP Tower Area (within Dist. 54)	1.13	2,271	109	2,380	1,215	129	1,344						
St. Paul Metro. Area; Urban Activity Dist.													
84-88(CBD)	0.80	12,508	109	12,617	6,359	129	6,488	5,367	131	5,498	4,510	133	4,643
79	6.00	1,743	109	1,852	977	129	1,106						
80	3.12	1,845	109	1,954	950	129	1,079						
81	6.60	1,521	109	1,630	830	129	959						
82	3.20	3,565	109	3,674	2,013	129	2,142						
83	6.88	3,202	109	3,311	1,764	129	1,893						
89	3.84	1,381	109	1,490	769	129	898						
90	13.48	779	109	888	436	129	565						
91	4.48	2,044	109	2,153	1,108	129	1,237						
92	7.28	1,298	109	1,407	719	129	848						
93*	3.80	1,517	21,509	23,026	836	27,549	28,385						

*Includes CO emissions from St. Paul Airport.

TABLE II-13

SUMMARY OF HYDROCARBON EMISSIONS WITH NO CONTROL STRATEGIES APPLIED FOR METROPOLITAN MINNEAPOLIS AND ST. PAUL

Location	Square Miles	Hydrocarbon Emission Density (kg/sq mile/12 hrs) 1971 Vehicles	1971 Other	1971 Total	1977 Vehicles	1977 Other	1977 Total
Minn. Metropolitan Area; Urban Act. Dist.:							
57 62 (CBD)	2.20	1,616	703	2,319	783	837	1,620
52	5.28	207	703	910	97	837	934
53	8.60	291	703	994	136	837	973
54	5.04	434	703	1,137	205	837	1,042
55	5.48	505	703	1,208	237	837	1,074
56	5.96	553	703	1,256	260	837	1,097
63	1.40	815	703	1,517	382	837	1,219
64	5.56	735	703	1,438	345	837	1,182
65	5.60	377	703	1,080	177	837	1,014
66	5.20	328	703	1,031	154	837	991
67	4.08	365	703	1,068	171	837	1,008
68	2.60	584	703	1,287	273	837	1,110
69	6.20	304	703	1,007	142	837	979
St. Paul Metropolitan Area; Urban Act. Dist.:							
84 88 (CBD)	0.80	1,603	703	2,306	779	837	1,616
79	6.00	334	703	1,037	164	837	1,001
80	3.12	357	703	1,060	164	837	1,001
81	6.60	282	703	985	136	837	973
82	3.20	698	703	1,401	343	837	1,180
83	6.88	579	703	1,282	285	837	1,122
89	3.84	259	703	962	127	837	964
90	13.48	148	703	851	73	837	910
91	4.48	389	703	1,092	185	837	1,022
92	7.28	239	703	942	117	837	954
93	3.80	274	703	977	135	837	972

- CO emissions from the St. Paul Airport were added directly to Urban Activity District No. 93.
- Hydrocarbon emissions from both the International and St. Paul airports were apportioned over the Minneapolis and St. Paul Metropolitan areas.

b. Vehicular Sources of Emissions

The VMT data presented in Section II C were utilized in conjunction with the automobile age distribution in Minnesota AQCR 131 (see Appendix G) and EPA automotive emission factors to estimate CO and hydrocarbon emissions for 1971 and 1977.

c. Discussion of Emission Densities

Examination of Tables II-12 and II-13 clearly indicate that the Minneapolis and St. Paul CBD's have significantly higher CO and hydrocarbon emission densities than other zones in the metropolitan areas. This is primarily the result of a high density of slow moving vehicles in the CBD's during the peak travel hours. The one exception is Urban Activity District 93 which contains the St. Paul airport. The CO emissions from this airport were added directly to District 93, making the emission density extremely high relative to the other Urban Activity Districts in the metropolitan areas. Because this high CO emission level in UAD 93 is due almost entirely to non-automotive sources (i.e. St. Paul airport), no transportation control strategies for this area are recommended in this report. Hydrocarbon emissions from the two airports because of the nature of the reactions which generate photochemical oxidants, were not assigned to their specific zones (the International Airport is located adjacent

to Urban Activity District 69), but instead were apportioned over the entire St. Paul and Minneapolis metropolitan areas.

2. 1977 CO Air Quality Levels

a. Relating Air Quality Data to an Appropriate Emission Density

Table II-14 presented below shows the highest 8-hour average CO concentrations recorded through July 1971, at the downtown Minneapolis and at the KSTP tower monitoring stations. The St. Paul monitor was not considered reliable by MPCA personnel and so the data were not included. The value of 26.2 ppm recorded at the KSTP monitor was the highest reported by either station. However, because of the extremely low CO emission density in the area of the tower (2380 kg/sq mile/12 hrs) relative to the emission densities in the two CBD areas (> 12,500 kg/sq mile/12 hrs), we feel that localized effects such as the nearby trucking operations and parking lot plus meteorology contributed to this high concentration level. We therefore concluded that it would be highly inappropriate to "roll back" the low emission density level of 2380 kg/sq mile (12 hours), by the 65.6 percent figure shown in Table II-14.

The value of 18.9 ppm measured by the Minneapolis monitor, on the other hand is located in an area of high emission density and we feel that the direct rollback technique in this case can be meaningfully employed. Utilizing such a roll back, Table II-14 illustrates that a 52.4 percent reduction in 1971 emissions is required in the Minneapolis

TABLE II-14

SUMMARY OF HIGHEST 8-HOUR CO CONCENTRATIONS

Location	Highest 8-hr Ave. CO Level (ppm)	Date Occurred	Percent Reiuction Needed to Meet Standards of 9ppm	Corresponding "Safe" Emission Density (kgm/sq.mile)	Percent Reduction Achieved by 1977 from Federal Motor Vehicle Control Program	Percent Reduction Needed from Control Strategies
Minneapolis CBD	18.9	11/11/71	52.4	6,100	48.7	3.7
St. Paul CBD	*	-	-	-	-	-
KSTP Tower Area	26.2	11/11/71	65.6	819	43.5	22.1

* Data not considered reliable by MPCA personnel and so was not included.

CBD to meet the CO 8-hour ambient air quality standard. The Federal Motor Vehicle Control Program can achieve 48.7 percent reduction, with the remaining 3.7 percent dependent upon the application of traffic control strategies. The safe emission density level of 6,100 kg/sq. mile (12 hours) (corresponding to the level that is achieved with a 52.4 percent reduction in Minneapolis CBD emissions) can therefore be utilized as the reference value in determining whether emission densities in other zones will result in acceptable or unacceptable CO air quality. Examination of the estimated 1977 total emission densities shown in Table II-12 indicate that all zones with the exception of the two CBD's (and zone 93 which contains St. Paul airport) will have emission density levels well below this 6,100 "safe" value.

b. Calculation of 1977 Air Quality Data

The projected 1977 CO air quality data without application of transportation control strategies can be calculated by the following equation, using the Minneapolis air quality and emission density data discussed above:

$$\left(\frac{C_{71}}{E_{71}}\right)_{\text{Minneapolis zone}} \quad E_{77}{}_{\text{Zone X}} = C_{77}{}_{\text{Zone X}}$$

where C = 8-hour average CO concentration (ppm)

E = Emission density [kgm/sq. mile (12 hour)]

The $(C/E)_{71}$ ratio for the Minneapolis zone is equal to:

$$\frac{18.9}{12,822} = 1.47 \times 10^{-3}$$

Figures II-14 and II-15 show the projected 1977 CO air quality for each of the Urban Activity Districts comprising the Minneapolis and St. Paul metropolitan areas. These figures indicate that only the two CBD areas exceed the 9 ppm 8-hour average CO standard (except for UAD 93 which has large CO emission levels from the St. Paul airport). Consequently transportation control strategies are necessary in the two CBD areas to achieve the CO standard by 1977. Such strategies will be needed to achieve:

- an additional 3.7% reduction in total 1971 CO emissions in the Minneapolis CBD by 1977, and
- an additional 3.1% reduction in total 1971 CO emissions in the St. Paul CBD by 1977.

Note, however, that without application of transportation control strategies, the Federal Motor Vehicle Control Program will result in achievement of the CO standards by 1978. This is shown in Table II-12 where the projected 1978 emission densities in the two CBD's fall below the "safe" level of 6100 kg/sq mile (12 hrs).

3. 1977 Oxidant Air Quality Levels

Table II-15 presented below shows the highest 1-hour average oxidant concentrations recorded through July 1971, at the downtown Minneapolis and KSTP tower monitoring stations. This table indicates that if the proportional rollback technique is applied to the highest oxidant value of 0.114 ppm, then a 28.4% hydrocarbon emission reduction is required in the area whose emissions resulted in these high concentrations. The hydrocarbon emission densities for the Minneapolis and St. Paul metropolitan area as presented in Table II-13, indicate that the two CBD areas have

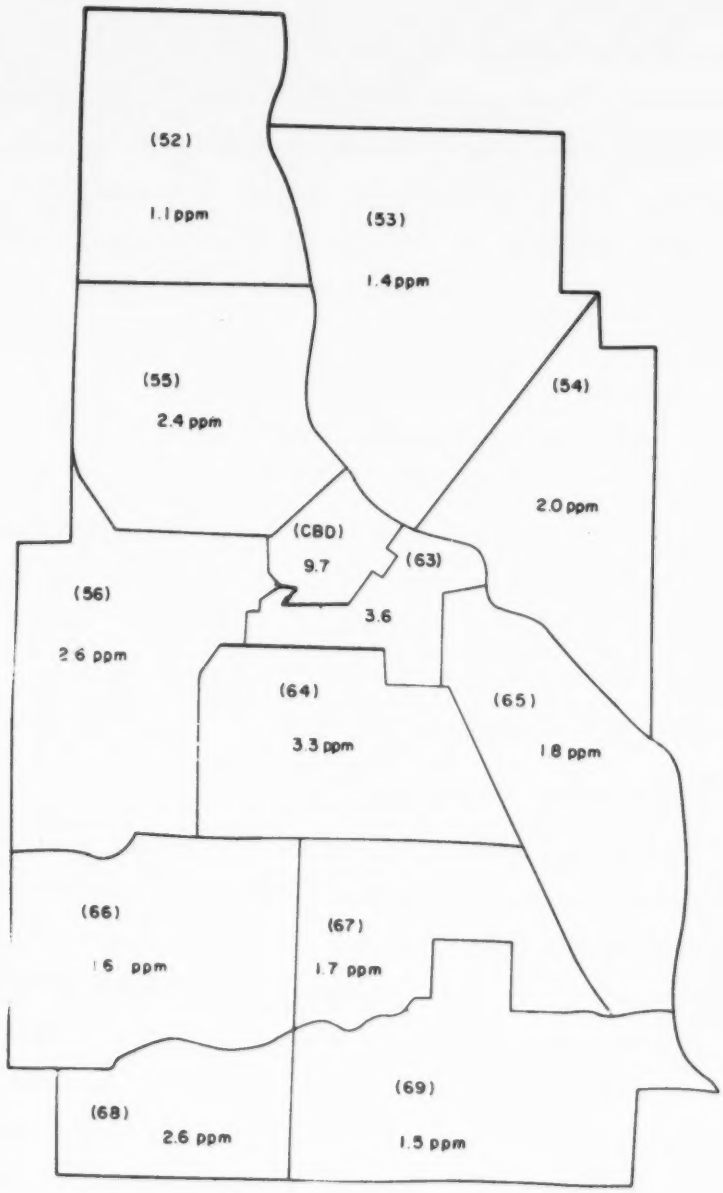

Figure II-14. Projected 1977 CO air quality for Minneapolis CBD.

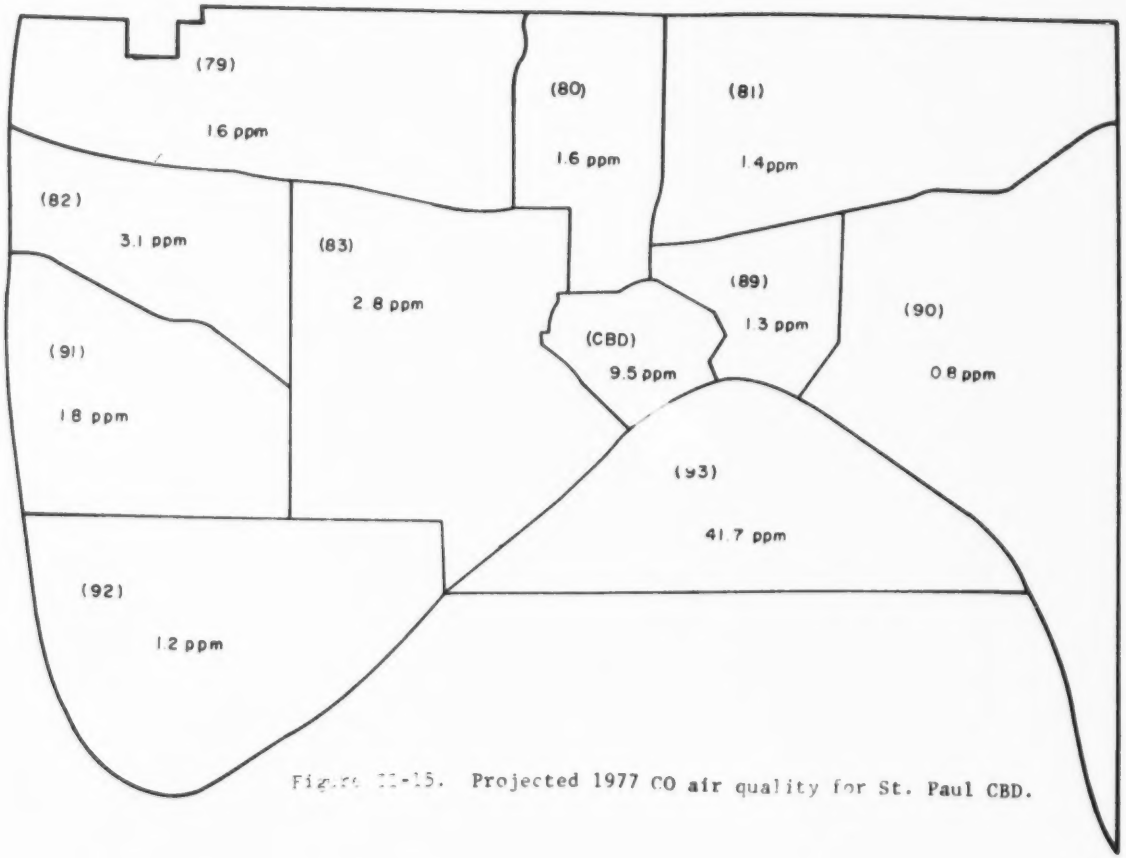

Figure II-15. Projected 1977 CO air quality for St. Paul CBD.

TABLE II-15

SUMMARY OF HIGHEST 1-HOUR OXIDANT CONCENTRATIONS

Location	High 1-hr Oxidant Level (ppm)	Date Occurred	Percent* Reduction Needed To Meet Standard of 0.08 ppm
Minneapolis CBD	0.114	7/71	28.4
St. Paul CBD	Not Available	-	-
KSTP Tower Area	0.095	Summer 1971	13.0

*From Appendix J, 42 CFR 420, Federal Register, Vol. 36, No. 158, Part II, August 14, 1971, p. 15502.

the most significant hydrocarbon emission levels by at least a factor of 2. GCA therefore postulated that excessive oxidant concentrations in the Metropolitan areas are the result of hydrocarbon emissions from the CBD areas, and that emission densities in the CBD's would have to be "rolled back" by at least 28.4% to achieve oxidant standards by 1977. Table II-13 shows, however, that the Federal Motor Vehicle Control Program will achieve this percent total hydrocarbon emission reduction in the CBD's:

CBD	% of 1971 Total Hydrocarbon Emissions Reduced by 1977
Minneapolis	30.1
St. Paul	29.9

Consequently, transportation control strategies will not be required to achieve the oxidant air quality standard by 1977.

E. CONCLUSIONS

In summarizing the above subsections, the following conclusions have been derived:

> 1-hr average oxidant air quality standards will be achieved by 1977 with the hydrocarbon emission reductions obtained from the Federal Motor Vehicle Control Program. In addition, the application of control strategies for non-vehicular sources, which were not considered in our estimates, would achieve further hydrocarbon emission reductions by 1977. GCA concludes, therefore that oxidant air quality standards can be achieved by 1977 in the Minneapolis St. Paul Metropolitan areas without the application of transportation control strategies.

- 8-hr average CO air quality standards will be achieved by 1977 in all areas of Region 131 with the exception of the Minneapolis CBD and St. Paul CBD with the CO emission reductions obtained from the Federal Motor Vehicle Control Program. Figures II-14 and II-15 show the projected 1977 air quality for each Urban Activity District comprising the Metropolitan Areas of Minneapolis and St. Paul.

- 8-hr average CO air quality standards will be achieved by 1978 in all areas of Region 131 including the Minneapolis and St. Paul CBD's, with the CO emission reductions obtained from the Federal Motor Vehicle Control Program.

- The reduction in 1971 emissions needed from Transportation Control Strategies, to achieve the 8-hour average CO standard in the Minneapolis and St. Paul CBD's by 1977 are as follows:

CBD	Reduction of 1971 emission density required by control strategies	
	%	Total kg/sq. mile (12 hr)
Minneapolis	3.7	475
St. Paul	3.1	391

III. STRATEGIES FOR IMPROVING AIR QUALITY THROUGH TRANSPORTATION CONTROLS

Since motor vehicle emissions constitute a major source of air pollution proportional to the extent of their use, the effectiveness of pollution control measures installed, and the nature and mode of their operation, a number of strategies have been proposed toward imposing some control over these parameters. These may be divided into three broad, general categories which:

1. Reduce the density of travel;
2. Control the effectiveness of emission controls and operational condition of the engine; or
3. Improve the speed, lessen periods of idle, acceleration and deceleration by improving traffic flow.

Typical of strategies falling under the first category are those which reduce the vehicle-miles of travel committed by private vehicles in problem areas. The objectives here are generally aimed at diversion of automobile trips to public transit, increasing car occupancy by encouraging car pools, and restricting auto travel completely thus forcing travel by other modes including walking. The strategies range from enhancing competivite attributes of other modes, regulation and enforcement of travel restrictions, and pricing policies to changes in working hours of employees.

Emission control measures are being installed on new cars which progressively meet stricter emission standards. At present, however, older

cars are not being required to meet these standards and control measures on new cars deteriorate with use. Therefore, the gradual improvement potential in the emissions of the automobile population depend upon the age distribution of the group and their maintenance. Strategies involving periodic vehicle performance inspection, periodic vehicle maintenance, and retrofit of older cars with available control devices are typical approaches being considered and, in some areas, applied to improve air quality.

Strategies for improving traffic flow and operations result in decreasing emission levels by increasing the average speed of engines, and therefore vehicles, reducing the travel time, the number of stops and idle time involved there, and the extent the vehicle must accelerate to cruise and decelerate while performing the trip. These improvements usually involve some sophistication in traffic control systems, removal of conflicts in traffic by parking and turning restrictions, turning lanes, and removal of conflicts between pedestrian and vehicle traffic by grade separation conversion to one way street flow, and other traffic engineering approaches. These are typical approaches usually incorporated in TOPICS (Traffic Operation to Improve Capacity and Safety) programs.

All of these are representative of viable candidates which must be tested in each community for individual measures of effectiveness, desirability, political and public acceptability and severity of the improvement required. A specific strategy which is beneficial in one area may prove ineffective, undesirable or even untenable in another. In some cases a single strategy may not be as effective as a combination of interrelated strategies carefully designed and coordinated. Prior to

selecting or evaluating strategies tailored to the Twin Cities area problem, a brief discussion of selected strategies will be given as background and possible future consideration. For the purposes of this study strategies must have potential benefit in the near term, say 5 years, as opposed to those providing reductions over a longer term only.

A. ALTERNATIVE STRATEGIES FOR REDUCING DENSITY OF TRAVEL

Density of travel is measured by vehicle-miles per square mile. Therefore, the aim of these strategies are generally at reduction of the number of vehicles and/or the distance travelled used to serve demands for travel. The work-trip is categorically the most troublesome travel for it generates peaks in traffic in the morning and evening, resulting in overstressing existing capacity of linkages between home and work. Congestion, at these periods results in longer travel times. Many consider it uneconomical to expand the corridor vehicular capacity to meet the peak-hour demands, only to have off-peak loads for below that capacity.

The work trip by auto is inefficient in another area. Car occupancy in vehicles in the Minneapolis area average only 1.52 persons per car. Although this is about the national average, existing road and street capacity can serve, obviously, more person-trips if more people could be carried per vehicle.

1. Improved Public Transit

One means of concentrating more person-trips into an efficient vehicle is that of diverting auto drivers and passengers to public

transit. Simple mathematics indicates that a bus carrying 55 passengers yet occupying slightly more than the equivalent of two standard automobiles is over 18 times as efficient in meeting the work-trip demands within existing capacity. Improved transit operations have been attempted in numerous areas. Those which merely increase frequency of service or reduce existing fares do not appear to be successfully competing with the comfort, availability, privacy, independence of movement and other positve attributes perceived by the auto user. Even though the bus operates in a very flexible manner in the collection and distribution phases of the trip, they can not offer the door-to-door transportation service of the private automobile.

An example of this is the Rapid Bus Transit operating on segregated busways of the Shirley highway in the Northern Virginia/ District of Columbia area offer a travel time advantage of about 30 minutes over car travel in the same corridor. Conversion of auto travellers to transit have been a small percentage of total travel to date. A three-year Urban Mass Transportation Administration demonstration program is in progress and considerable improvement is anticipated. These conclusions may be premature. Other incentives, such as suburban fringe parking which provide an intercept function by permitting part of the trip to be performed by car from home to parking lot and frequent bus service from fringe parking to the CBD and an effective CBD distribution system may result in more bus patronage and less automobile work-trip travel.

All travellers, including those in higher income ranges, are sensitive to "perceived" trip costs. Where pricing policies other

than fare adjustments are combined with improved level of service and other changes, additional conversion to transit can be realized. This will be discussed in a following section.

One study of a transit improvement in the Twin Cities area[1] indicated that auto use in and within about 2 miles of downtown could be reduced in the long term, about 15 years, by about 13 percent. On a regional basis, a reduction of about 3 percent in 1985 auto use compared to current use could be expected from test systems producing the largest diversion. Air pollution impacts for alternative transit systems in the Twin Cities is subjectively summarized in Table III-1.

2. Improved Transit Combined with Other Pricing Policies

Pricing policies may be combined with improvements in transit to realize increased patronage of transit by the auto traveller. These policies include substantial increases in parking fees in the CBD for all-day parking, increased tolls for single occupancy cars, commuting taxes, and other monetary assessments against private vehicle use.

An oft-cited example is the Philadelphia-Lindenwold system which has obviously made its mark on improving rail rapid service. Its sole impact on reducing highway congestion is difficult to measure. It is apparent that vehicular traffic over two corridor bridges has reduced about 7 percent. Two factors external to the system confound the analysis

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[1] Voorhees, Alan M. and Associates, Inc., Development of a Long Range Transit Improvement Program for the Twin-Cities area, Twin-Cities Metropolitan Transit Commission, November 1969.

TABLE III-1

AIR POLLUTION IMPACTS FOR ALTERNATIVE TRANSIT SYSTEMS IN TWIN CITIES[2]

System	Direct Air Pollution Impact	
	Downtown	Regional
Rapid Rail Transit	Excellent	Negligible
Rapid Rail Transit with Extended Station Spacing	Excellent	Negligible
Buses in Freeways and Streets	Fair	Negligible
Commuter Railroad	Good	Negligible
Busways without CBD subways	Fair	Negligible
Busways with CBD subways	Fair	Negligible
Metered Freeway Buses	Fair	Negligible

[2] Ibid.

of the diversion: The tolls applied to private cars had been increased 100% during the period, but only 25% for commutation tickets, and the depressed economic conditions in the Camden area. A user survey indicated that a large percentage of the ridership on the system represented passengers diverted from other transit service rather than from private cars.

While transit patronage has been found to be relatively inelastic with respect to fare changes[3][4], parking fee policies appear to offer another strategy to discourage private auto use for the work trip. A study in the Minneapolis-St. Paul area in 1958[5] indicated that doubling the parking rate resulted in an increase in transit patronage from about 30 percent to about 45 percent. To achieve a level of 80 percent transit usage, the model indicated that a quadrupling of parking fees would be required.

Similar models have been developed for the Baltimore area relating parking fees to transit ridership. Although some results have not been satisfactorily explained, particularly within the first increments of change, the model did forecast a transit ridership above 50 percent for a daily parking cost of $2.50 or higher. The lowest income group would perform about 80 percent of travel by transit, while about 50 percent of the highest income group's travel would be by transit. The Baltimore

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[3] Lassow, W., Effect of the Fare Increase of July 1966 on the number of Passengers Carried on the New York City Transit System, Highway Research Record No. 213, 1968.

[4] Curtin, J.F., Effect of Fares on Transit Riding. Highway Research Record No. 213, 1968.

[5] U.S. Dept. of Commerce, Bureau of Public Roads, Model Split, Documentation of nine methods for Estimating Transit Usage, Government Printing Office, 1966.

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study assumed a large rapid transit system with substantial improvement in transit travel time. With a quadrupling of parking costs, relatively large diversions could be obtained from the upper income groups.(6)

Many assumptions were made in the development of these models. The data are encouraging from an air pollution reduction standpoint. However, much more research is required to reliably relate driver reactions to cost differential factors. Direct application to other areas should be discouraged.

3. Improved Transit Combined with Other Transportation Regulations

Parking bans in the CBD tend to divert auto trips to areas where parking is available if the trip can be completed satisfactorily by other travel modes. If the parking is provided in the outer fringes, the auto trip will be short and on relatively uncongented street networks. If the parking is available on the CBD fringe, vehicle-miles of travel to those facilities will still be generated and could possibly shift the pollution from the CBD to the surrounding areas. Such parking facilities would require some distribution system improvement in the CBD if walking distances are greater than several blocks. Mini-buses or other micro-transit systems such as people-mover systems can respond to these requirements.

A combination of CBD fringe parking and shuttle bus service to CBD distributions has proved successful in Atlanta. A demonstration of

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(6) Voorhees, Alan M. and Associates, A Report on Mode Choice Analysis for the Baltimore Region, HMV-R-20-1043 (921).

this concept indicates that the auto driver will patronize such a combined facilitation and avoid the congestion in the CBD. Many of the attributes of the private car are retained by the scheme.

Another approach falling possibly in this category is the various priority treatments afforded buses to increase levels of service and shorten the time of the bus rrip. Priorities include preferential bus lanes, exclusive bus streets, extension of green phase of traffic signals by approaching buses, metered on-off ramps on expressways for buses during peak hours, and segregated busways inhance the quality of bus service. Some of these measures can be applied at relatively low investment costs by traffic control regulations, while others may require substantial capital improvements.

4. Decreasing Traffic Density through Car Pool Incentives

Another means of decreasing traffic density is to encourage car-pooling. As an example, if car occupancy in private cars were to double in Minneapolis from the present 1.5 to 3.0, a reasonable objective, the vehicle-miles commuted to the work trip would be reduced by 50 percent. Various incentives have been tried to accomplish this objective with mixed results. They include providing preferential parking by the employer to car-pool vehicles, special toll rates for high-occupancy vehicles, shared use of reserved freeway lanes with buses, and other priviledges to car pool operators. Basic negative factors are that the car pool passengers must live in proximity of each other, have common work hours and locations, and be compatible in other respects. Car-pools of persons

who may work unscheduled over-time are not successful because of inconvenience to others in the pool. Concepts to overcome some of these negatives need to be developed. The general area appears to be a fruitful one if sufficient strategies can be devised.

5. Decreasing Traffic Density through Changes in Work Hours

Consideration has been given to the 4-day 40-hour work week for employees. This would potentially reduce the number of work trips over the work week by 20 percent. If spread over six days, a theoretical 10 percent reduction in daily vehicle-miles would be realized. Difficulties in establishing these practices include the interfaces between commercial enterprises which require some commonality of working periods with other enterprises. Availability of free time for three off-days will probably induce more recreational travel but not necessarily in problem areas.

6. Shuttle Bus Service

Downtown districts developed as compact pedestrian-oriented centers and must continue and be revitalized at a pedestrian scale. Pedestrian CBD circulation studies indicate that people desire to limit their walking-trips to something less than 1,500 to 2,000 feet and will pay a premium to achieve this convenience. These trips reflect movement from parking and transit terminals to major employment centers, to and from shops in the concentrated retail core, and interbuilding trips for business or eat-meal purposes.

Where pedestrian volumes and distances fall within certain ranges, augmentation of the pedestrian trip by some form of transporta-

tion should be considered. Within certain ranges of these parameters and operating costs, shuttle bus service appears to be feasible for a CBD distribution system.

Since short headways between vehicles is usually desired, small, 15 to 25 seat "mini-buses" are often employed in this type service, operating on existing streets or exclusive bus lanes in malls. Where demands warrant larger, conventional buses may be employed. Where shuttle bus service is employed to interconnect concentrated points of demand, such as a CBD-fringe parking facility, buses perform collection and distribution functions in the core, with frequent closely spaced stops at employment centers and retail shops and stores. The movement is subject to delays due to conflict with other vehicles on shared street facilities. Benefits can be realized from priority measures and other treatments relative to bus transit to shortening the trip time.

7. People-Movers (Micro-systems)

Most transportation systems are "people-movers", however, this term applies to micro-systems which range from moving walk-ways to bi-rail and monorail systems. These systems should provide maximum service in a minimum distance and be limited in length to maximize the number of passengers in each mile of route. The micro-system should serve, rather than bypass, major retail and office concentrations, complement line-haul transit rather than compete and follow linear movement channels.

Factors favorable to micro-system development include: extensive core area congestion; limited parking in core areas; antici-

pated rapid center city growth; extensive urban renewal prospects; and major barriers to movement within the center city. In considering micro-systems, movement distances should be greater than 700 to 1,000 feet in order that a significant reduction in trip times over walking can be realized. High capital costs suggest need to serve heavy pedestrian concentrations. The economic feasibility of micro-systems as alternatives to shuttle buses depends upon the relationship of capital and operating costs to patronage levels. In a recent study, comparisons were made between assumed operating bus costs and construction costs of alternative micro-systems.[7] At a bus operating cost of $1.20 per mile, a patronage of 8,000 to 13,000 persons or more per mile average eight-hour volume, made a micro-system whose construction cost was assumed to be $2,000,000 per mile, more attractive. A volume of 20,000 to 32,000 persons per mile per eight-hour day would be required to justify a micro-system whose construction cost is $5-million per mile. A micro-system costing $15,000,000 per mile becomes feasible at a volume between 60,000 and 90,000 passengers per mile.

For a micro-system to effectively intercept autos at the periphery of the CBD, the following factors should be considered. The free market demand for micro-system riding to peripheral parking facilities would come from that group of downtown employees and visitors who are now walking long distances to avoid high parking costs. These usually represent only a limited portion of the total parkers. Would these persons be

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[7] Wilbur Smith and Associates, Urban Transportation Concepts--Center City Transportation Project, September 1970, for the Urban Mass Transportation Administration, U.S. Department of Transportation.

willing to pay rates high enough to capitalize both new peripheral garages and a micro-system without other measures? Under most circumstances, it is felt that some additional incentives would be necessary to realize the potential. One strategy often considered is the limitation through regulation and control of the number of spaces available in the core. Another is to increase core parking charges to that well in excess of park-ride costs. These disincentives combined with effective and economic park-and-ride facilities are thought to be necessary to assure patronage and reduce core parking.

B. STRATEGIES FOR CONTROL OF EFFECTIVENESS OF EMISSION CONTROLS AND OPERATIONAL CONDITION OF ENGINES

Automobile manufacturers are providing a reduction of emission levels on new vehicles through changes in engine design and installation of emission control devices. These measures, while effective when the vehicle is new, tend to deteriorate with vehicle use depending upon the nature of the measure and the periodic maintenance given the vehicle during its life. Inspection/maintenance strategies have been implemented in a number of states to assure that these means are effective throughout the vehicle life. Two general categories of strategies have been identified: an engine parameter inspection followed as necessary by specified parameter maintenance; and mode emission signature analysis producing further diagnosis and corrective maintenance. Each of these approaches contains a number of substrategies and tactics. The major discriminate between these categories is the instrumentation employed in the inspection and the methods of performing the diagnosis.

An economic effectiveness study has been performed[8] to evaluate the more significant substrategies and tactics and to develop figures of merit, cost per inspection/maintenance per car, and to optimize emission reduction for each substrategy.

The engine characteristics involved in both tests were idle, with and without load, ignition misfire, and air induction. Within the weighting factors assigned to the emission components (CO, HC and NO_x) reductions, the "best" alternative within a given strategy can be assessed from the data summarized in Table III-2. Procedures compared here include the inspection performed in a state inspection lane and by a franchised operator or garage.

In addition to an idle adjustment program, other parameter inspection/maintenance strategies were assessed as indicated in Table III-3. In these cases, the overall figures of merit were found to be considerably poorer than that of the idle adjustment program. Although these more elaborate procedures substantially reduce HC emission levels below that obtained by the idle adjustment procedures, they are more than offset by higher costs. These costs are the result of more difficult and lengthy inspections required to find ignition and induction system malfunctions. For example, the study indicated that 15 minutes of inspection time on 100 percent of the vehicles would be required to find the 3 to 4 percent of engines with misfire defects under load. Only in regions of chronic air pollution and large vehicle population would such costs appear warranted.

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(8) TRW Systems Group et al., The Economic Effectiveness of Mandatory Engine Maintenance for Reducing Vehicle Exhaust Emissions, Vol. 1, APRAC/CAPE-13-68, CRC & EPA, August 9, 1971.

TABLE III -2

SUMMARY OF THE MORE COST EFFECTIVE
INSPECTION/MAINTENANCE PROCEDURE

Procedure	Figure of Merit ($/Ton)	Cost Per Vehicle ($)	Emission Reduction***		
			HC (%)	CO (%)	NO (%)
Engine Parameter Diagnosis					
1. Idle (State Lane)	320	1.50	0	15	-7
2. Idle (Franchised)	370	2.50	3	13	-3
3. Extensive A* (Franchised)	460	6.00	18	14	0
4. Extensive B** (Franchised)	540	13.00	22	33	-5
Emission Signature Analysis					
5. Idle (State Lane)	430	2.50	2	12	-4
6. Extensive A* (State Lane)	360	4.00	11	16	-4
7. Extensive B** (State Lane)	410	4.00	15	20	-3

*Idle Plus Ignition Subsystem Inspection.

**Idle Plus Ignition Plus Induction Subsystem.

***Average emission reduction over a four-year period.

Source: TRW Systems Group et al., The Economic Effectiveness of Mandatory Engine Maintenance for Reducing Vehicle Exhaust Emissions, August 9, 1971.

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4. Extensive B** (Franchised)	540	13.00	22	33	-5
Emission Signature Analysis					
5. Idle (State Lane)	430	2.50	2	12	-4
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7. Extensive B** (State Lane)	410	4.00	15	20	-3

*Idle Plus Ignition Subsystem Inspection.

**Idle Plus Ignition Plus Induction Subsystem.

***Average emission reduction over a four-year period.

Source: TRW Systems Group et al., The Economic Effectiveness of Mandatory Engine Maintenance for Reducing Vehicle Exhaust Emissions, August 9, 1971.

TABLE III -3

EQUIPMENT AND PROCEDURES REQUIRED FOR DIAGNOSING
ENGINE PARAMETER MALFUNCTIONS

Subsystem	Engine Parameter		Emission Signature	
	Equipment	Procedure	Equipment	Procedure
Idle				
- Rpm	Tachometer	Idle Rpm	NDIR HC Analyzer	Idle HC
- Timing	Timing Light	Basic Timing	NDIR HC Analyzer	Idle HC
- Fuel-to-Air	NDIR CO Analyzer	Idle CO	NDIR CO Analyzer	Idle CO
Ignition-Misfire	Engine Electronic Analyzer Dynamometer	Misfire at 45 mph road-load	NDIR HC Analyzer/ Dynamometer	45-Mph HC
Induction				
- PCV	Pressure gage	Idle Crankcase pressure	NDIR CO Analyzer/ Dynamometer	45-Mph CO
- Air cleaner	AC air cleaner tester	Pressure drop across element	NDIR CO Analyzer/ Dynamometer	45-Mph [illegible]
- Air reactor	NDIR CO/CO_2 Analyzer	Idle dilution correction	NDIR CO Analyzer/ Dynamometer	CO Connected - CO Disconnected

Source: TRW Systems Group et al., The Economic Effectiveness of Mandatory Engine Maintenance for Reducing

The reductions cited here are those which were realized immediately after the inspection/maintenance procedure. Therefore, the values must be degraded on some basis and as a minimum, linearly with time over a 12-month period to obtain realistic reduction estimates.

The procedures discussed above were for idle engine mode. This test mode is not considered to be capable of achieving and maintaining a suitable emissions reduction and is generally not acceptable to EPA as the ultimate procedure, although has been judged a useful first step toward the implementation of an acceptable inspection/maintenance strategy. A preferred program includes diagnostic maintenance, mandatory maintenance and loaded emission inspection programs.

Programs for pre-controlled vehicles at a minimum must cover the following engine parameters: PCV value, air cleaner, idle adjustments, spark plug wires, points, condenser, spark plugs, and distributor cap and rotor. Programs for controlled vehicles must include any emission control-related component or adjustment for which the manufacturer recommends periodic servicing. Inspections at least once a year will provide the following reductions:

Hydrocarbons	12%
Carbon Monoxide	10%
Nitrogen Oxides	0%

The loaded test procedures require the use of some form of calibrated load to be applied to the vehicle drive chain such as a chassis dynamometer. Not only does this requirement increase inspection costs, it likewise requires additional test set-up time, therefore decreasing the throughput of inspection lines.

C. STRATEGIES RELATED TO IMPROVED TRAFFIC FLOW

Any measure would be beneficial in decreasing vehicle pollution which would smooth the flow of traffic or increase the average speed of the traffic stream. Some measures which reduce congestion might be counter productive, however, because that might induce more people to drive. Other measures might be required concomitantly with traffic operation improvements to reduce overall number and length of auto trips in problem urban areas.

The techniques for improving traffic flow on freeways are relatively well developed. They include: reverse lane operations, where one or more lanes are employed for moving traffic selectively during various times to meet direction of flow demand; driver advisory displays indicating alternative routes and advising motorists of traffic conditions; ramp control or metering where freeway access is permitted consistent with freeway traffic volumes; and interchange design to more adequately accommodate weaving or merging maneuvers.

Arterials are commonly obsolete for modern traffic demands. Much can be done to improve their effectiveness, as demonstrated in TOPICS programs. These techniques include: modifications to horizontal alignments to remove small radius curves; decreases in vertical grades to main constant speeds; widening intersections by minor construction and elimination of curb parking; reversible lanes and one-way streets; channelization of traffic flow; turning lanes for left turn maneuvers, and other traffic engineering techniques.

The street system in the CBD is often judged as the most complex component of the urban area road system. Traffic flow is frequently interrupted by pedestrian movements, turning vehicle conflicts, a high number of start-stop transit vehicles in the traffic stream, and traffic signals. Lower average speeds result from the vehicle time spent at idle, accelerating and decelerating.

In addition to the measures employed by TOPICS designs, a traffic responsive signal control system has proved beneficial in improving downtown circulation. In Wichita Falls, a such system reduced vehicle stops by 16.3%, average vehicle delays by 31 percent and increased peak-hour speeds on many downtown approach and exit streets from 20 to about 30 miles per hour.

In many downtown areas, loading and unloading of commercial vehicles impedes smooth traffic flow. One effective measure to lessen the immediate problem is peak-hour restrictions on such operations.[1] Another is the designation of service streets segregated as much as possible from the arterial street system. The long-range solution is the establishment of off-street loading facilities. Urban goods movements by truck are also inefficient in that small consignments are delivered by many truck trips rather than combined loads in a smaller number of trucks.

Pedestrian/vehicle conflicts can be minimized by special controls, creation of pedestrian malls and grade separation of pedestrian traffic from vehicular traffic.

Staggering of work hours can effectively spread peak-hour transportation demands for both private vehicles and transit. This effectively permits more effective use of existing street capacity and facilitates traffic flow. Demonstration programs in such towns as Atlanta, New York and other cities have proved the workability of such approaches.

D. CANDIDATE STRATEGIES FOR MINNEAPOLIS-St. PAUL

In this study, a relatively small reduction in traffic density is required in the CBD's of Minneapolis and St. Paul to achieve Federal air quality standards by 1977 as seen in Section II D. The implementation of already planned programs in these cities would appear to potentially achieve at least the magnitude of reductions required. Under these circumstances, no additional strategies other than those specified in these programs were examined in this report, and these strategies are discussed below.

1. Candidate Strategies for the Minneapolis CBD

a. Express Bus Service - Planning for an express bus service is already underway for the I-35W Urban Corridor. The service will be operating initially as a demonstration program. Continuation of the service will be based upon the results of the demonstration and the availability of funds to support the service, if required.

Full operation of the service is planned for mid-1973. It will include ramp-metering facilities on the freeway. It is anticipated that the service will divert approximately 2,000 riders daily from automobiles. On the assumption that these trips are all work-trips, this

means a decrease of about 2,700 automobiles in that corridor, (4,000 person-trips daily at an occupancy of 1.5 persons per car). The ADT in 1970 on I-35W is about 100,000 vehicles. Thus the impact in the corridor, and for that matter in the CBD, would have a minor impact on reducing the traffic density and therefore the emission levels in either area, when taken by itself.

b. CBD Fringe Parking - The concept of providing convenient, low cost parking at the fringe of the CBD along with restricting and discouraging parking the the core is expected to be implemented by 1976. Parking ramps totaling 11,350 spaces connected to the distribution network and freeways on one end and pedestrian skyways into the core on the other will be effective incentives for their use. Also, the elimination of a like number of spaces in the core will be further inducement supporting the plan. Thus, it can be estimated that about 16,500 auto passengers will be diverted from the CBD. With an estimated 363,000 two-way person-trips into the CBD, this would correspond to a potential reduction in passenger-car vehicle-miles of about 9 percent. Assuming an 80% utilization of the fringe parking facility, by 1977, about 7 percent reduction in passenger VMT can be assumed to be a reasonable influence.

c. People-Mover System - Planning is currently underway by the City of Minneapolis, Metropolitan Transit Commission and the downtown Council for an automated people mover system in downtown Minneapolis which would provide linkage between CBD fringe parking facilities, downtown offices and stores and the skyway system. The system would consist of

20-40 passenger vehicles operated on a fixed guideway elevated to the second story level of downtown buildings. The maximum walking distance from any point in the downtown area to a people-mover station is expected to be 2 1/2 blocks and average 1 to 1 1/2 blocks. The first stage of the system--the east-west loop--is anticipated to be operational by 1976. Half of the total mileage will be operational at this time.

This planned system or some other pedestrian-augmentation facility has already been assumed in operation to serve the CBD fringe parking benefits for Minneapolis. Therefore, the further impact of this system on reducing CBD VMT volumes will be minimal and be largely the reduction in private cars making internal CBD trips between activity centers. It is estimated that this circulation presently is about 1 percent of total passenger car volume.

d. Traffic Surveillance and Control - Detailed planning for a traffic-responsive surveillance and control system has been completed for Minneapolis. The volume, speed and direction of vehicles along controlled CBD streets will be monitored. The data will be transmitted to a central computer to determine cycle phase of traffic signals, providing an adaptive signal system. The system is to control reverse lanes and divert traffic from congested streets. The system will require 3 years to implement and is expected to be operational by the first quarter of 1976.

Similar systems have been operational in a number of cities of the same size. The results of these demonstrations vary widely. The

effectivity of the computerized signal system not only depends upon the location and number of sensors or detectors used in measuring traffic conditions, but is vitally concerned with the computer algorithms employed to develop effective control programs. The results therefore depend upon both hardware installation and design, and upon skillful computer programming. The effectivity also depends upon careful analysis of conflicts in traffic flow and corrective measures implemented to lessen these problems.

Experience has shown that if an optimum system has been provided, substantial improvement in average traffic speed can be realized. It is felt that the average speed in the CBD can be increased from the present 14 mph to about 20 mph.

2. Candidate Strategies for the St. Paul CBD

a. Fringe Parking - Bulk parking facilities in the fringe of the St. Paul CBD is part of the present policy of both the City of St. Paul and the downtown business community. Long-term employee parking structures are planned on the periphery of the core. Executive parking in limited quantities convenient to place of employment and in structures are a part of this policy. Shopper, business and patron parking in structures convenient to destinations is supported by the policy. Errand parking off-street and well distributed is included along with regulation and pricing to encourage short term use. The policy also embraces the elimination of all on-street parking in the retail and office areas.

Specifically proposed action by OPERATION '85, the development arm of the Downtown Business Association, includes the development

of three open parking lots to provide spaces for 10,000 cars, with expansion as necessary as multi-level facilities. These plans, if associated with an effective shuttle bus service also planned, could contribute to the reduction in CBD traffic volume, with the provision that a like number of spaces are eliminated in the core. This elimination would fit into the above stated policy and should be definitely committed in that development.

On the basis of past assumptions, about 15,000 persons would be diverted from the CBD core. When comparing this to the number of person-trips projected for the area in 1977 and proper accounting for the vehicle travel that would be generated by these trips, it is estimated that about a 10 percent reduction in passenger car VMT volume related to the CBD can be realized.

b. Shuttle Bus Service- A shuttle bus service is in integral part of the recommended strategy for the fringe parking program of OPERATION '85. The service would supplement the expanding skyway system and would provide transportation from the parking facilities with the downtown area.

In addition, the Metropolitan Transit Commission's unified work program for 1973 includes a circulation and collection/distribution study for St. Paul. The study, with support from the Urban Mass Transportation Administration will be a six-month effort which may lead to design of a transportation center to interconnect the fast link system, the shuttle bus system and other transit with the St. Paul Skyway system.

Such a program will enhance the circulation downtown and contribute to the improvement of core circulation.

c. Auto Free Malls - The transportation plan for the St. Paul Core Area recommends an Auto Free Mall on Seventh Street between Jackson and Wabasha. Auto Free malls have also been proposed for Fourth and Minnesota. Only shuttle buses would operate on these streets.

These facilities would not, in themselves, substantially contribute to the reduction of traffic volume in the core, and may be counter-productive by inducing vehicle travel into the Core area. Fringe parking and shuttle bus service discussed above will be adequate, however, to off-set the attraction of downtown travel of shoppers.

d. Traffic Signal System - Improvements in the traffic signal system have been proposed as part of the St. Paul TOPICS plan. With the same comments made to the Minneapolis Traffic Signal system applicable here, substantial improvement in core area travel speed should be realized. It is estimated that an increase from 12 mph to about 18 mph is a realistic and achievable objective for this program. With such potential, this program should be supported by this air quality implementation plan.

IV. OBSTACLES TO IMPLEMENTATION OF CANDIDATE CONTROLS

A. RESEARCH METHODOLOGY

Research on the issues associated with the implementation of transportation controls to improve air quality consisted of a systematic process of data collection, interpretation and evaluation, as shown in Figure IV-1 below. The first step was to review the candidate strategies for transportation control identified by the traffic engineer. Once this preliminary list was known, it was possible to identify the public agencies and private interest groups at city, state and regional levels, who would have an interest in the implementation of these strategies. This process was facilitated in Minneapolis-St. Paul by an early informational meeting to which representatives of a large number of public agencies were invited.

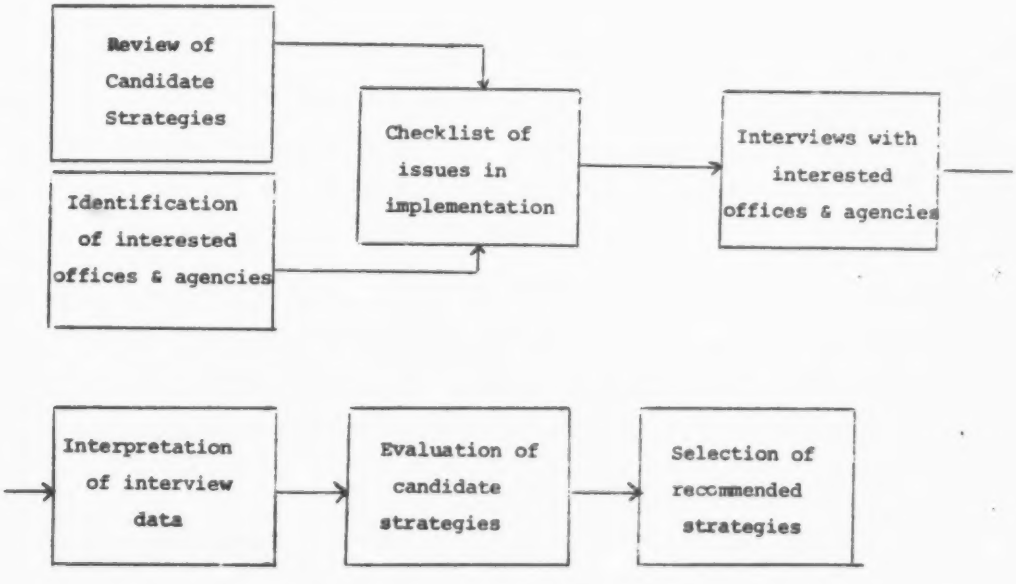
Review of Candidate Strategies
Identification of interested offices & agencies
Checklist of issues in implementation
Interviews with interested offices & agencies
Interpretation of interview data
Evaluation of candidate strategies
Selection of recommended strategies

Figure IV-1. Research Methodology.

Given brief descriptions of the candidate strategies, a list of interest groups, and an understanding of the problems generally associated with change in the urban environment, it was possible to identify the types of issues (or sometimes, obstacles) that might be associated with implementation of the transportation controls. A general checklist of the types of issues anticipated was prepared for subsequent review with representatives of interested parties. The checklist consisted of the following items:

- Legal Authorization and Requirements
- Financial Requirements: amount of funding needed; type and sources of financing possible
- Management and Enforcement Responsibility
- Economic Impact
- Political Feasibility
- User Acceptance

Interviews were held with representatives of virtually all of the public agencies who might be concerned about the candidate control measures, and with representatives of downtown business. Other citizen interest groups were not interviewed at this stage. Each of the relevant candidate control strategies was discussed in terms of the types of issues included in the checklist. Respondents also provided us with reports and other written material relevant to the issues being discussed. Suggestions for alternative strategies were also solicited at this time. Lists of the people interviewed in Minneapolis, St. Paul and Salt Lake City can be found in Appendix A.

The qualitative data resulting from the interviews was interpreted in light of our growing understanding of the transportation issues

active in the cities at the present time, and our understanding of the political and economic forces that must be balanced in the urban environment. This information, in conjunction with the written material supplied, made it possible to evaluate the candidate transportation control strategies in terms of the timeliness and feasibility of their implementation. From this evaluation, recommendations were made for the selection of transportation control strategies.

In Minneapolis - St. Paul, only the vehicle performance inspection was eliminated from the list of candidate strategies finally recommended. The problems associated with the implementation of such a program are discussed in Appendix B.

B. EVALUATION OF STRATEGIES RECOMMENDED FOR MINNEAPOLIS' CENTRAL BUSINESS DISTRICT (CBD)

1. Express Bus Service

Planning for the major portion of the express bus service recommended here is already underway in the form of the I-35W Urban Corridor Demonstration on a Bus-Metered Freeway System. Full operation of the service, including metered entrance ramps for the buses, is expected by mid-1973. It is anticipated that the service will attract approximately 2,000 riders daily from their automobiles.

The service will be operating initially on a demonstration basis. Continuation of the program will depend on its initial success, as indicated by the results of continuous evaluation, and on the availability of additional funds for operation.

a. Legal Authorization and Requirements

Legal authority to manage and operate such an express bus on an Interstate Freeway exists within the combined authorities of the Metropolitan Transit Commission and the Minnesota Highway Department. The land required for the construction of the metered freeway ramps is within the highway right of way, and no additional land acquisition will be required for this purpose. Since the buses will operate with other vehicular traffic on the freeway itself, no additional right of way will be required here either.

b. Management and Enforcement Responsibility

The project is managed by a Project Management Board consisting of representatives of the Metropolitan Council (coordinates all planning in the Seven County area), Minnesota Highway Department, Metropolitan Transit Commission, Hennepin County and the City of Minneapolis. The Board provides overall technical direction for the project. The project director is a full time staff member of the Minnesota Highway Department and is the individual responsible for dealing with the Consultants and coordinating local staff participation. Expansion of the project to include St. Paul would require expansion of the Project Management Board to include appropriate city and county representatives.

c. Financial Requirements

The capital cost for all elements of the Bus-Metered Freeway system has been estimated at $4,731,000, including the surveillance and control system ($1,703,000) and the bus ramps, vehicles, park-

ride facilities, waiting shelters, and bus stop signs that comprise the transit service ($3,028,000). The annual operating expenses of the transit service plan are estimated at $558,000 for the first year. Additional operating funds will be necessary for the surveillance and control system ($148,000) and marketing ($102,150).

Financial support for the demonstration project has been committed from several sources: Federal Highway Administration, Urban Mass Transit Administration and the Metropolitan Transit Commission. However, operation of the express bus system beyond the demonstration phase will require a small amount of additional financing. As indicated in the final planning report on the system,* operating expenses for the first year are expected to be as follows:

Service Plan Operation	$ 558,800
Surveillance & Control System	148,000
Marketing	102,150
Total Operating Cost	$ 808,950
Passenger Revenues	$ 689,700
Operating deficit offset by initial grants and local service reductions	($119,250)

In the second and subsequent years, we can expect passenger revenues to increase by about 5% (extrapolation of current trend in the Minneapolis, St. Paul metropolitan area) and marketing costs to be reduced by about $30,000 (3/4 of the expenses for creative planning and

*I-35W Urban Corridor Demonstration Project: Bus Metered Freeway System, September, 1971.

advertising for metering). Thus, for the second and subsequent years, additional financing of $54,765 would be required to support the program, as shown below:

Service Plan Operation	$ 558,800
Surveillance & Control System	148,000
Marketing	72,150
Total Operating Cost	$ 778,950
Passenger Revenues	$ 724,185
Operating Deficit Requiring additional financial support	$ 54,765

It is possible that this sum could be financed by the State or by a continuing grant from the Federal Highway Administration. Resolution of this issue must await evaluation of the program's first full year of operation.

Also awaiting evaluation of this demonstration program is the expansion of freeway metering and express bus service to connect Minneapolis and St. Paul. This project would require substantial capital and operating financing of the same order of magnitude as the I-35W corridor project.

d. User Acceptance

Vital to the success and continued operation of the express bus service is the market's acceptance of it. In recognition of this fact, the system planners have already devoted considerable effort to the marketing strategy. The major appeal would be made on the basis of the time and money saving features of the system. An attitudinal study for the Twin

Cities Area Metropolitan Transit Commission conducted in early 1969 by Simpson and Curtin showed the importance of a number of characteristics of transit travel to work, shown below in Table IV-1. Percentages refer to the percentage of the sample who ranked the trip characteristics as "very important" or "of some importance".

TABLE IV-1*

RANKING OF CHARACTERISTICS OF TRANSIT TRIPS TO WORK

	Very Important	Of Some Importance	Total
Getting to Work on Time	91.6%	5.6%	97.2%
Your Safety	83.3%	13.0%	96.2%
Travel Time	55.1%	26.0%	81.1%
Need Not to Transfer from one Bus to Another	54.2%	25.1%	79.3%
Having your Mind free while going to and from work	39.0%	40.9%	79.9%
Your Comfort	36.8%	41.8%	79.6%
Cleanliness of the Car	31.9%	52.9%	84.8%
Cost of the Trip	26.0%	36.2%	62.2%

While all of these factors are of considerable importance, as indicated by the total percentages, it is clear that getting to work on time and other travel time issues are paramount. If the credibility of time saving by bus can be established with auto users, then this should be the major

*I-35W Urban Corridor Demonstration Project: Bus Metered Freeway System, September, 1971, p. 107.

thrust of the marketing appeal. Other factors, especially safety and convenience should also be highlighted. Less money should probably be spent on advertising the money saving features of the system, (now targeted for major emphasis) because of the relatively little importance ascribed to this characteristic by potential users. Since the primary market (auto users of the corridor) consists of people with higher than average income, this appeal is likely to have little impact. With these minor changes in the marketing strategy, it seems possible that the system will achieve the anticipated ridership goals.

e. Economic Impact

The major economic impact anticipated at this time is a reduction in parking lot revenues normally received from auto commuters. This would not amount to more than about $3,000 per day, and be spread among a large number of parking lot owners. Since reductions in the number of downtown parking spaces are planned, it is not likely that this impact will be sufficient to present an obstacle to full implementation of the express bus service.

f. Political Feasibility

The political feasibility of the service depends, ultimately, on the attitudes of users and downtown employers and parking lot owners. If they continue to support it, there is not likely to be any political opposition.

2. CBD Fringe Parking

The concept of providing convenient, low cost parking at the fringe of the CBD, while restricting and discouraging parking in the

downtown core is an integral part of current planning for Minneapolis. The Metro Center '85 report* includes as policies

> "Creation of fringe parking ramps connected to the distributor network and freeways on one end and pedestrian skyways into the core on the other.
>
> Prohibiting through zoning, the development of any new parking ramps within the core by restricting the maximum number of parking spaces that may be permitted in any new building."

Full implementation of the city's parking policy is anticipated by 1976, by which time peripheral parking ramps will be in operation with a total of 11,350 spaces. By the same time, through the redevelopment of the downtown area, approximately 11,000 CBD spaces will be eliminated.

a. Legal Authorization and Requirements

Minneapolis has the legislative authority necessary to develop parking facilities in the locations it desires. Minnesota Statutes Chapter 459 include the right to issue bonds to finance parking facilities, securing low interest rates with the full faith and credit of the city. Through the power of eminent domain, Minneapolis has the right to acquire the necessary land and to build on it.

The City's capacity to limit the private construction of parking facilities is less clear. While it is legally possible for the city to restrict parking through its zoning powers, developers are frequently granted the right to construct parking in excess of the desired

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*Metro Center '85: Study for Development of Program and Priorities for Expanded Job and Investment Opportunities in Central Minnesota, Minneapolis Planning and Development, March, 1970, p. 102.

200 spaces per block of development in exchange for other concessions. To remedy this situation, it will be necessary to redraft the present zoning ordinance to explicitly restrict parking in the downtown area to accessory parking (less than 200 spaces per block of development), and to prohibit construction in this area of any major new facilities intended exclusively for parking. The new zoning ordinance will require passage by the city council. As indicated in the Metro Center '85 report,* restriction of downtown parking through zoning and redrafting of the zoning ordinance is the policy of the city. Several new versions of the ordinance have been prepared, and agreement is anticipated shortly. The City's parking policy has the full support of the Minneapolis Downtown Council (the development arm of the Chamber of Commerce) and can thus be expected to pass the City Council.

Another tool potentially available to control the location and quantity of downtown parking in Minneapolis is the development district. Chapter 677 of the 1971 Minnesota State Statutes authorized the creation of two development districts until 1973. In the 1973 legislative session, the City will propose that the downtown area also be designated a development district, thereby giving the City unprecedented control over the design and location of all new construction in designated areas. City planners are presently identifying the possible boundaries of a downtown development district, and no opposition has yet arisen to the plan.

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*Metro Center '85, p. 140.

b. Financial Requirements

Bonds have already been sold for a major portion of the fringe parking structures, and the remainder are in preparation. It is likely that arrangements will be made with the operators of the parking garages to guarantee the City a fixed annual income from the facilities sufficient to repay the initial investment and debt service. Although it is not anticipated that any additional financing will be necessary, grants are available from the Federal Highway Administration for the construction of parking ramps for commuters in conjunction with Interstate Highway projects.

Another financing alternative, proposed in the Metro '85 report is the creation of a parking fund which would be the recipient of money from private downtown developers for the construction of a required number of parking spaces. Pooling of this money in a special fund would make it possible to construct parking more efficiently and at locations chosen by the City rather than at the development sites.

c. Management and Enforcement Responsibility

Management of CBD fringe parking ramps would be delegated to the operators to whom the facilities were leased.

Responsibility for the revision of the zoning ordinance and the possible creation of a downtown development district rest with the City Planning and Development Department and the Coordinator's office.

d. User Acceptance

Acceptance of CBD fringe parking in lieu of downtown core area parking will depend somewhat on the price of the parking, but much

more on the quality and timeliness of the linkage to downtown that is provided. A people mover system and an expanded skyway system are planned for this purpose, and discussed below.

e. Pricing Controls

Also at issue is the possible institution of pricing controls which would raise the price of downtown CBD parking in relation to fringe CBD parking. This would theoretically discourage all but executives and perhaps shoppers (whose parking fees might be paid through their purchases) from parking in the CBD. The economic impact of this policy could be detrimental to downtown parking operators and even downtown stores who could be at a disadvantage in relation to suburban businesses. At present, the City does not have the right to review parking rates. And a new City ordinance would be required to implement these controls. Such an ordinance would require council approval. Given its economic disadvantages, it is unlikely that this policy will be politically feasible within the period of the implementation plan.

3. People Mover System

Planning is currently underway by the City of Minneapolis, Metropolitan Transit Commission and the Downtown Council for an automated people mover system in downtown Minneapolis which would provide an efficient linkage between CBD fringe parking facilities, downtown offices and stores, and the skyway system. The system would consist of 20-40 passenger vehicles operating on a fixed guideway elevated to the second story of the downtown buildings. The maximum walking distance from any point

in the downtown area to a people mover station is expected to be 2 or 2 1/2 blocks, and the average about 1 or 1 1/2 blocks, it is anticipated that the first stage of the system - the east, west loop comprising half the total mileage - will be operating by 1976.

a. Legal Authorization and Requirements

Chapter 429 of the 1971 Minnesota State Statutes permits the city of Minneapolis to finance, construct, operate and maintain a people mover system of the type contemplated. However, additional legal steps must be taken before construction can begin. Agreements will need to be reached between the City and all of the individual property owners abutting the proposed right of way. One problem which may interfere with this process is the system's potential infringement on the abutting property owners' right to light and air. If this becomes a serious issue, then delays are likely to result.

b. Financial Requirements

The initial capital investment required for the system has been estimated at $53,000,000, with annual operating expenses of $3,100,000 including debt service. On-going negotiations with the Urban Mass Transit Administration indicate that approximately 80% federal funding may be available for the initial capital investment.

Minneapolis has in mind several options for financing the remaining costs. One option would involve the creation of an economic development district in downtown Minneapolis and the application of tax increment financing. Under this scheme, taxes in the district are frozen

at the level of a designated year, and the increase in tax revenue resulting from the improvement (the people mover, in this case) is returned exclusively to the district, through the general fund. The potential for creating an economic development district within the city of Minneapolis exists in Chapter 677 of the 1971 State Statutes. However, application of this law to downtown Minneapolis would require approval of the Legislature sometime after July 1, 1973. An additional constraint on the use of this funding mechanism is a current limit of 5 mils on the additional tax levy that can be made on the property owners in a development district. This revenue would cover only about one fourth of the cost of the system.

If this restriction were not lifted, then additional revenue would be required from other sources.

Construction of the people mover system, however, is not dependent on approval of Minneapolis as an economic development district. The city of Minneapolis itself and the Metropolitan Transit Commission are both prepared to sell bonds to raise the initial capital required. A benefit assessment district could also be established with the beneficiaries of the service being assessed in proportion to their benefit. If necessary, it would also be possible to charge a 10 cent fare to defray operating expenses, instead of the service being free.

The financing options for this proposal are many, and its ultimate feasibility rests with the economic strength of the entities involved and not with which option is chosen. The City of Minneapolis

has an AAA bond rating, and the Metropolitan Transit Commission an AA rating. Thus it appears that some satisfactory financing scheme can be found to implement the people mover system.

c. Management Responsiblity

Responsibility for management of the people mover system is now under discussion, and the obvious candidates are the city of Minneapolis and the Metropolitan Transit Commission. A decision about this is expected shortly.

d. Economic Impact

The people mover system is likely to have a positive economic impact on retail sales, office space leasing, and development of tourist and convention facilities. Land values are likely to increase near the stations. No groups have been identified which would be likely to suffer economically as a result of the people mover service.

e. User Acceptance

Acceptance by the residents of Minneapolis will depend largely on the financing scheme that is chosen, the quality of the service, and perhaps the aesthetic impact of the aerial structure itself. Until the financial and design details have been decided, it is not possible to anticipate citizen response.

f. Political Feasibility

While there is substantial support for the concept of the people mover system, political opposition may arise during the process

of detailed design and location. This can and is being avoided by involving the downtown business community early in the system's planning.

4. Traffic Management System

Detailed planning for a traffic surveillance and control system (or traffic management system) has been completed for Minneapolis. The system will monitor the number, speed and direction of vehicles along the controlled roadways. This information will be fed into a computer which will coordinate the signal system, meter traffic, reverse lanes and divert traffic from congested streets as appropriate in order to optimize the smooth flow of vehicular traffic. The system will require 3 years to implement, and is expected to be operational by the first quarter of 1976.

a. Legal Authorization and Requirements

No special legal authorization is required to install the system. Maintenance agreements between Minneapolis, Hennepin County and the State of Minnesota will have to be prepared to define maintenance responsibilities on the roads belonging to these different political entities. There is ample time to reach an agreement on this issue, and it is not expected to be an obstacle to the system's operation.

b. Financial Requirements

The traffic management system will cost about $4,000,000 and be supported by a TOPICS grant from the Federal Highway Administration for approximately $2,000,000 (50%). Twenty percent of the remaining $2,000,000 will be paid for by the City, and 30% by Minnesota and

Hennepin County. The funding has been authorized informally and official approval is anticipated very shortly.

c. Management and Enforcement Responsibility

Management of the system will rest with the City of Minneapolis and enforcement of the traffic regulations will remain with the police now in force on the affected streets.

d. User Acceptance

There may be resistance to the system from travelers who, during peak travel periods, are diverted from their intended direction and must find alternate routes to their destination. Opposition may arise from truckers and other delivery services (Postal Service, etc.) who may find it difficult to follow their accustomed routes. These problems are not expected to be sufficient to interfere with the system's implementation, but may reduce its efficiency for a few months until travelers have become accustomed to it.

e. Political Feasibility

There are no political problems anticipated at this late stage in the planning.

f. Economic Impact

Implementation of the traffic management system will change the flow of traffic, but is not expected to increase the total number of vehicles that regularly enter the city. Thus no significant economic impact is expected.

C. EVALUATION OF STRATEGIES RECOMMENDED FOR ST. PAUL CENTRAL BUSINESS DISTRICT (CBD)

1. Central Business District Fringe Parking

The creation of bulk parking facilities at the fringe of the St. Paul CBD is part of the present policy of both the city of St. Paul and the downtown business community. The parking concept for the St. Paul area* includes:

- "Long-term employee parking in structures located on the periphery of the core on the minor arterial system.
- Executive parking in limited quantity located convenient to place of employment and in structures.
- Shopper, business and patron parking in structures and very convenient to destinations.
- Errand parking off-street and well distributed with regulation and pricing to encourage short stays.
- Eliminations of all on-street parking in the retail and office areas."

Operation '85, the development arm of the downtown business association, has proposed specifically that bulk parking (open lots) be developed in three locations:

(1) Civic Center Ramp area to Chestnut Street and between Seventh Street and Shepard Road.

(2) The area of the railroad yards east of the Union Depot and east of the new Toni facility between Kellogg and Fifth Street.

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*Transportation Plan for the St. Paul Core Area, Bather, Wolsfeld, Inc., July, 1970, p. 22.

(3) The state capitol area including all the area not in public ownership south of Arch Penn between Rice and Jackson Streets.

Together, these lots would provide parking spaces for 10,000 cars, and could be expanded, as necessary, as multi-level facilities.

a. Legal Authorization and Requirements

The City of St. Paul has the authority necessary to acquire land for parking purposes. Several legal steps would be necessary, however, to implement the Operation '85 plan. In the case of the Civic Center area, additional land would need to be acquired by the Housing and Redevelopment Authority to expand the capacity of the Civic Center Ramp. Long-term agreements for the use of the area near the Burlington Northern Tracks would need to be drawn between the railroad, City and parking lot operators. In the vicinity of the Capital complex, an urban renewal program of acquisition and clearance would need to be established involving the Capital Approach Planning Commission and the Housing and Redevelopment Authority, with the support of the City and other organizations cited. All of these legal actions are possible within several months, or a year maximum.

b. Financial Requirements

The cost of the parking program outlined above has not been determined. However, since open lots are planned initially, the total cost should be relatively low. Operation '85 has recommended that the Industrial Bond Act currently used by the Port Authority of St. Paul be amended by the next State Legislature to include parking ramps and

parking lots in the scope of possible funding activities. This would permit private parking lot operators to enjoy the benefits of public acquisition of land and lower financing. If this option is not approved by the legislature, then the land could be acquired privately or by the City of St. Paul.

In order to further encourage drivers to park in the fringe lots, steps must be taken to discourage peak hour travelers from parking downtown. This can be accomplished by prohibiting the construction of large CBD parking facilities and controlling the price of downtown parking.

The City has the authority to restrict construction of downtown parking ramps through zoning. However, the St. Paul Housing and Redevelopment Authority presently requires that developers provide 1 stall for every 1500 square feet of office space. A change in this requirement will require approval by the Redevelopment Board, and a vote of the City Council and approval by the Mayor.

Another mechanism for discouraging downtown parking is the control of parking fees. This approach is understood by the business community to be unfair to downtown lot operators whose revenues would be likely to drop. The City of St. Paul now has the authority to set maximum parking rates, but not minimum. Given local opposition to this approach, it is not likely that the City council would approve an expansion of the City's authority for this purpose.

c. Management Responsibility

As currently conceived, the proposed parking facilities would be managed and operated privately. This does not pose any obstacles to the implementation plan.

d. Economic Impact

The overall economic impact of this plan is expected to be positive, in that now vacant or underutilized land will be put to a more productive purpose. As long as convenience and executive parking is not curtailed, there should be no negative economic impact on downtown businesses and retail stores.

e. Political Feasibility

There is no major opposition to the plan at present, and approval by the City Council is anticipated.

f. User Acceptance

Use of the parking facilities by travelers downtown will depend primarily on the convenience of the linkage to the core area. It is expected that this will be accomplished initially through the skyway system and a shuttle bus service, and eventually by a people mover system. The first two alternatives will be operative by 1977.

2. Shuttle Bus Service

A recommendation has also been made by Operation '85 to operate a shuttle bus service connecting the bulk parking facilities,

including the capitol area, with the downtown area. The following routes are being considered: During the hours of 7:00 a.m. to 9:30 a.m. and 3:30 p.m. to 6:00 p.m. buses would run on Fourth Stree from the Civic Center Ramp on the west, to and through a bulk parking area owned by the Burlington Northern on the east; from 9:30 a.m. to 6:00 p.m. buses will also make a loop through the Seventh Street retail area. The shuttle bus service would supplement the expanding skyway system and could be supplanted by the people mover system proposed for a later time.

The Metropolitan Transit Commission's unified work program for calendar year 1973 includes a circulation and collection/distribution study for St. Paul to begin in the third quarter of 1973 and continue for 6 months. The total cost of the study would be $50,000, of which the Urban Mass Transportation Administration would pay two-thirds. They indicate that the study "may lead to the design of a transportation center with facilities for the fast link systems, shuttle bus systems, and other bus services all interfacing with the St. Paul skyway system."*

a. Legal Authorization and Requirements

The Metropolitan Transit Commission has the authority to operate a shuttle bus service in downtown St. Paul.

b. Financial Requirements

Financing is available to conduct the study, and additional funds would be needed to purchase, operate and maintain the shuttle

*Memorandum: Unified Work Program, CY 1973, To Transit Development Committee from Cam Andre, Oct., 1972.

buses. Two-thirds funding would probably be available through the UMTA Capital grants program for purchase of the buses. Operation and maintenance would have to be supported by a fare or by taxes.

c. Management Responsibility

The Metropolitan Transmit Commission would have responsibility for managing the program.

d. Economic Impact

The service would be expected to improve the economic situation of downtown businesses. Without it, concentration of parking on the fringe of the CBD could discourage growth in the core area.

e. Political Feasibility

The shuttle bus service has the support of the downtown business community as well as local governing agencies. No political obstacles are anticipated.

f. User Acceptance

Acceptance of the service by users will depend on the waiting and travel times, and the quality of the wait and the ride. If the buses operate on short headways and in special bus lanes, and if waiting can be done in a heated, attached bus shelter, the service should be successful.

3. Auto Free Malls

The Transportation Plan for the St. Paul Core Area* recommends an auto free mall on Seventh Street between Jackson and Wabasha.

*Bather, Wolsfeld, Inc. July, 1970.

Auto free malls have also been proposed for Fourth and Minnesota. Only shuttle buses would operate on these streets.

a. Legal Authorization and Requirements

Implementation of this plan would require approval of the Mayor and City Council. There are no legal problems associated with closing the streets to automobile traffic.

b. Financing Alternatives

There are several ways in which the street improvements needed for the malls could be financed. One approach would be to designate the area a benefited district and assess the abutting property owners in proportion to the benefits they receive. The revenues collected from the benefit assessment could be used to repay the bonded debt for the improvements. Another possibility would be to request to the state Legislature that the area be declared a special development district. This would permit the increment in tax revenues over the base year to be used to finance these and possibly other improvements. The City of St. Paul could also use general tax revenues to pay for the project. Given these alternatives and the financial capacity of the City, financial considerations do not appear to be an obstacle to the project.

c. Management Responsibility

Management of the project would depend, in part, on how it was financed, but would rest ultimately with the City of St. Paul.

d. Economic Impact

The economic impact of the Seventh Street Mall is likely to follow that of Nicollet Mall in Minneapolis where retail business has

improved substantially. In recognition of this potential, Operation '85 and the downtown business community have spoken out in favor of the proposal.

e. Political Feasibility

The only potentially significant political obstacle to auto free malls could arise from the truckers unions who may need to make deliveries to the stores and business along the mall. This opposition can be overcome by improving off-street loading facilities at the rear of the buildings or making other arrangements to accommodate this need.

f. User Acceptance

The Nicollet Mall in Minneapolis has enjoyed great popularity among shoppers and sightseers and the malls proposed for St. Paul can be expected to bring the same response.

4. Traffic Signal System

Improvements to the traffic signal system have been proposed in St. Paul's TOPICS plan and are supported by this air quality implementation plan.

a. Legal Authorization and Requirements

The Department of Public Works of the City of St. Paul, with approval of the Mayor and City Council, has the authority to implement changes to the traffic signal system and street network.

b. Financial Requirements

The improvements proposed will be supported by the Federal Highway Administration's TOPICS program. Informal commitment of funds has been made and formal approval is expected.

c. Management and Enforcement Responsibility

The City of St. Paul will retain responsibility for operating the signal system.

d. Economic Impact

The TOPICS program will improve traffic flow and thereby encourage more people to travel into the downtown area. This should have a small, but beneficial, economic impact.

e. Political Feasibility

There is no political opposition to the TOPICS program.

f. User Acceptance

Since the system will improve mobility in the downtown area, it should be welcomed by downtown drivers.

V. SELECTION OF TRANSPORTATION CONTROLS AND ESTIMATE OF AIR QUALITY IMPACT

From the above presentation of the candidate strategies and their obstacles for the Minneapolis and St. Paul CBD's, the strategies of:

- express bus service, and
- auto-free malls

were stated to have a negligible impact on the density of vehicular travel; effectiveness of emission controls and vehicle speed and/or traffic flow. Consequently these two strategies were estimated to have negligible impact on the level of vehicular emissions in the CBD's. The following candidate strategies, however, do have a significant influence on vehicular emissions and their impact is evaluated in this section of the report:

MINNEAPOLIS CBD

Strategy 1: Fringe parking combined with people mover system estimated to reduce 1977 light duty VMT's by 8%.

Strategy 2: Traffic surveillance and control estimated to increase average speed in Minneapolis CBD from 14 mph to 20 mph by 1977.

ST. PAUL CBD

Strategy 1: Fringe parking combined with shuttle bus service estimated to reduce 1977 light duty VMT's by 10%.

Strategy 2: Traffic signal system estimated to increase average speed in St. Paul from 12 mph to 18 mph by 1977.

TABLE V-1

IMPACT OF CANDIDATE STRATEGIES ON CO EMISSIONS AND AIR QUALITY IN CBD'S

CBD	Area (Sq. Miles)	EMISSION DENSITY (kg/sq. mile/12 hours)					AIR QUALITY (Highest 8-Hour Average CO Concentration in ppm)				
		1971	"Safe" Emission Density Level	1977: No Transport. Controls Applied	1977 Appl. of Strategy #1	1977 Appl. of Strategies #1 & #2	1971	Ambient Air Quality Standard	1977: No Transp. Controls Applied	1977: Appl. of Strategy #1	1977: Appl. of Strategies #1&#2
Minnea-polis	2.2	12,822	6,100	6,571	6,164	4,703	18.9	9	9.7	9.1	6.9
St. Paul	0.8	12,617	6,100	6,488	5,983	4,664	18.6	9	9.5	8.8	6.8

Table V-1 summarizes the impact of these strategies on total emissions and on air quality in the two CBD's. Examination of this table indicates that CO ambient Air Quality Standards are approximated in both the Minneapolis and St. Paul CBD's by application of the #1 candidate strategy: Fringe parking and accompanying people mover or shuttle bus system. By additionally applying the second strategy in the CBD's,i.e. traffic surveillance and control in Minneapolis and a traffic signal system in St. Paul, the air quality is upgraded to levels well below the 9 ppm standard.

Based on the results illustrated in Table V-1, GCA recommends that the two strategies for each CBD presented here be implemented If fringe parking and accompanying shuttle transportation to the core area were adopted in both CBD's without traffic surveillance and control, it is unclear from the inherent accuracy band of the data, whether CO standards can indeed be achieved. Implementation of traffic surveillance and control procedures as well, will provide enough margin of safety to confidently assure that the standard can be achieved.

VI. SURVEILLANCE REVIEW PROCESS

There are three levels of surveillance review that are recommended to MPCA for each of the control measures adopted, and these review levels are:

- Reviewing progress in implementing selected control measures
- Reviewing impact of control measures on VMT and/or traffic flow in CBD's
- Reviewing impact of control measures on air quality.

Each of these areas of surveillance will be discussed below.

A. IMPLEMENTATION OF SELECTED CONTROL MEASURE

Figures VI-1 and VI-2 present Surveillance Review Milestones which indicate the dates at which critical activities, necessary for the successful implementation of each strategy, are currently planned to be completed. These figures show milestones for the implementation of all candidate strategies presented in Sections III and IV, including two, Express Bus Service for Minneapolis and Auto Free Malls in St. Paul, which were not included in Section V as part of the recommended control measures. They are included here as additional information in the likelihood that they are recommended by MPCA.

B. IMPACT OF CONTROL MEASURES ON TRAFFIC PATTERNS

Table VI-1 presents the effect of the recommended control measures as presented in Section V on the 1977 VMT's and the traffic flow conditions for both CBD areas. The surveillance program utilized

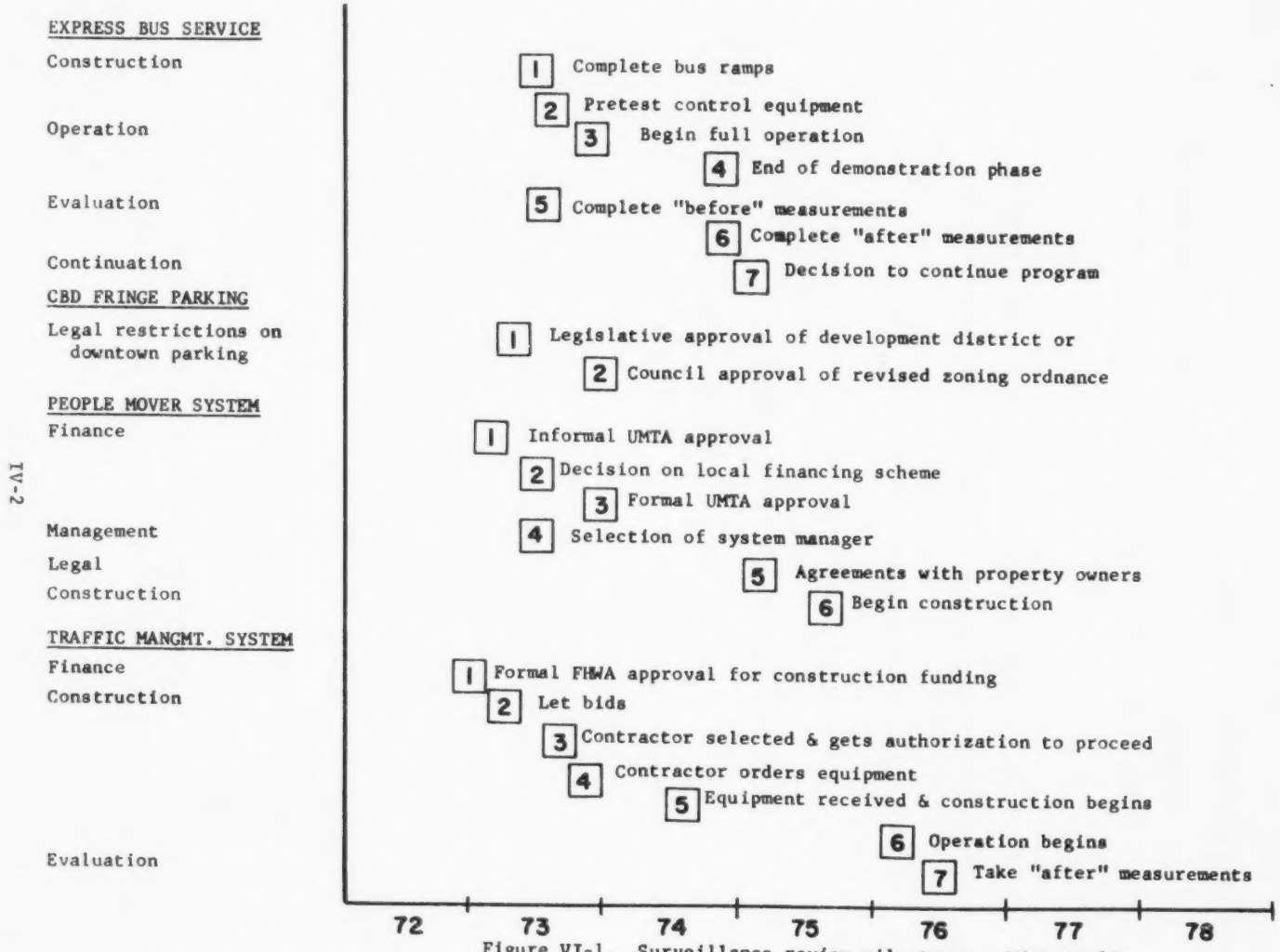

Figure VI-1. Surveillance review milestones - Minneapolis.

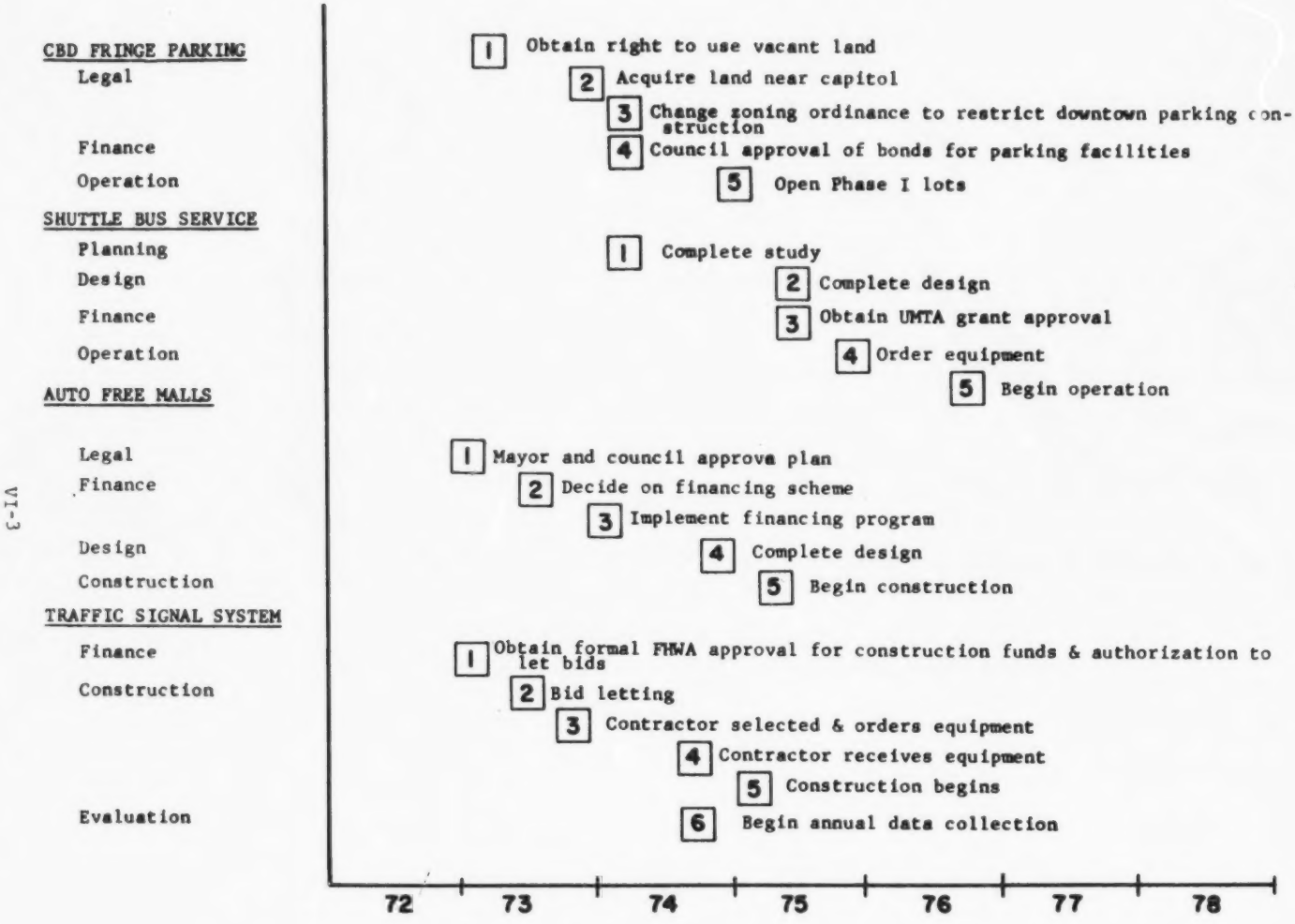

Figure VI-2. Surveillance Review Milestones - St. Paul

TABLE VI-1

EFFECT OF RECOMMENDED CONTROL MEASURES ON VMT'S AND TRAFFIC FLOW FOR THE MINNEAPOLIS AND ST. PAUL CBD'S

CBD	Area	Light Duty VMT's (12 hours)			Average Traffic Speed on Arterials (mph)		
		1971	1977: No Controls	1977: Recommended Controls	1971: No Control	1977: No Control	Recommended Controls
Minneapolis	2.2	266,000	321,000	296,000	14	14	20
St. Paul	0.8	96,500	116,500	105,000	12	12	18

to determine progress in attaining these 1977 conditions should include the following considerations:

1. Traffic Density

Estimates of annual daily traffic (ADT) are made from periodic surveys conducted by the Traffic Divisions or Section of the Municipal Departments of Public Works. From these data, updates of traffic density estimates on the CBD streets can be made following the procedures illustrated in this study. Annual trends should be maintained from these estimates and compared with the baseline 1971 and 1977 estimates. From such updates the gross measure of traffic flow can be made.

2. Traffic Operating Speeds

These data were basically derived by the Traffic Engineering studies performed by the municipalities. These data are gathered by a number of means. The "floating car" method is perhaps the most suitable. In this technique, a car is driving in mixed traffic at various times of the day and the average speed along determined route segments measured. By these sampling techniques average speed is determined which is weighted against prevailing volumes. Data should be obtained on a before-and-after improvement basis to determine speed trends.

3. Travel Behavior Inventories

Data obtained by sampling procedures, either conducted for transportation study updates by the Highway Department, the Twin Cities Area Transportation Department, or established under other special pur-

poses, should be analyzed and compared with basic data in the latest Travel Behavior Inventory used in projecting travel demand in this study. These updates should indicate meaningful developing trends in person trips, trip purposes, origins and destinations, car ownership, and other socioeconomic travel factors. Changes in these data from predicted trends should be assessed as to the impact upon VMT projections made here.

4. Parking Facility Inventory

The surveillance program should maintain inventories of number, type and location of core parking spaces to monitor the planned shift of availability of these from core to fringe of the downtown. Profiles of user characteristics should be developed and updated periodically to detect shifts in these patterns from planned objectives. Development of new centers of core activity should be monitored to assure that the parking policies are being followed.

5. Micro-System Circulation

Whether fringe parking is successful will depend upon the pedestrian augmentation provided. Therefore the surveillance program should monitor their development against the implementation schedule. Patronage volumes and use patterns will probably be determined as part of facility development. Trends in these data should be assessed against the assumed developments incorporated in this study.

C. IMPACT OF CONTROL MEASURES ON AIR QUALITY

Figures VI-3 and VI-4 indicate the predicted effect of the transportation control measures recommended in Section V on CO air quality in the two CBD areas. These figures can only be used as guides, however, due to the unpredictable nature of meteorological parameters which will greatly affect 8-hour average CO concentrations.

Both figures indicate that air quality will tend to improve linearly due to the Federal Vehicle Control Program but with no additional transportation controls. Since both recommended controls in Minneapolis, namely fringe parking and people mover systems, are not scheduled for partial completion until 1976, a straight line relationship was assumed between 1975 where no effect of controls of air quality is expected, and 1977 where the highest 8-hour average CO concentration of 6.7 ppm is projected.

For St. Paul, fringe parking is anticipated to commence in 1975 with the opening of the Phase I lots. Shuttle bus operation as well as the traffic signal system will not be operational until 1976. A straight line relationship was therefore assumed between 1974 where no effect of control on air quality is expected and 1977 where the highest 8-hour average concentration of 6.6 ppm is estimated.

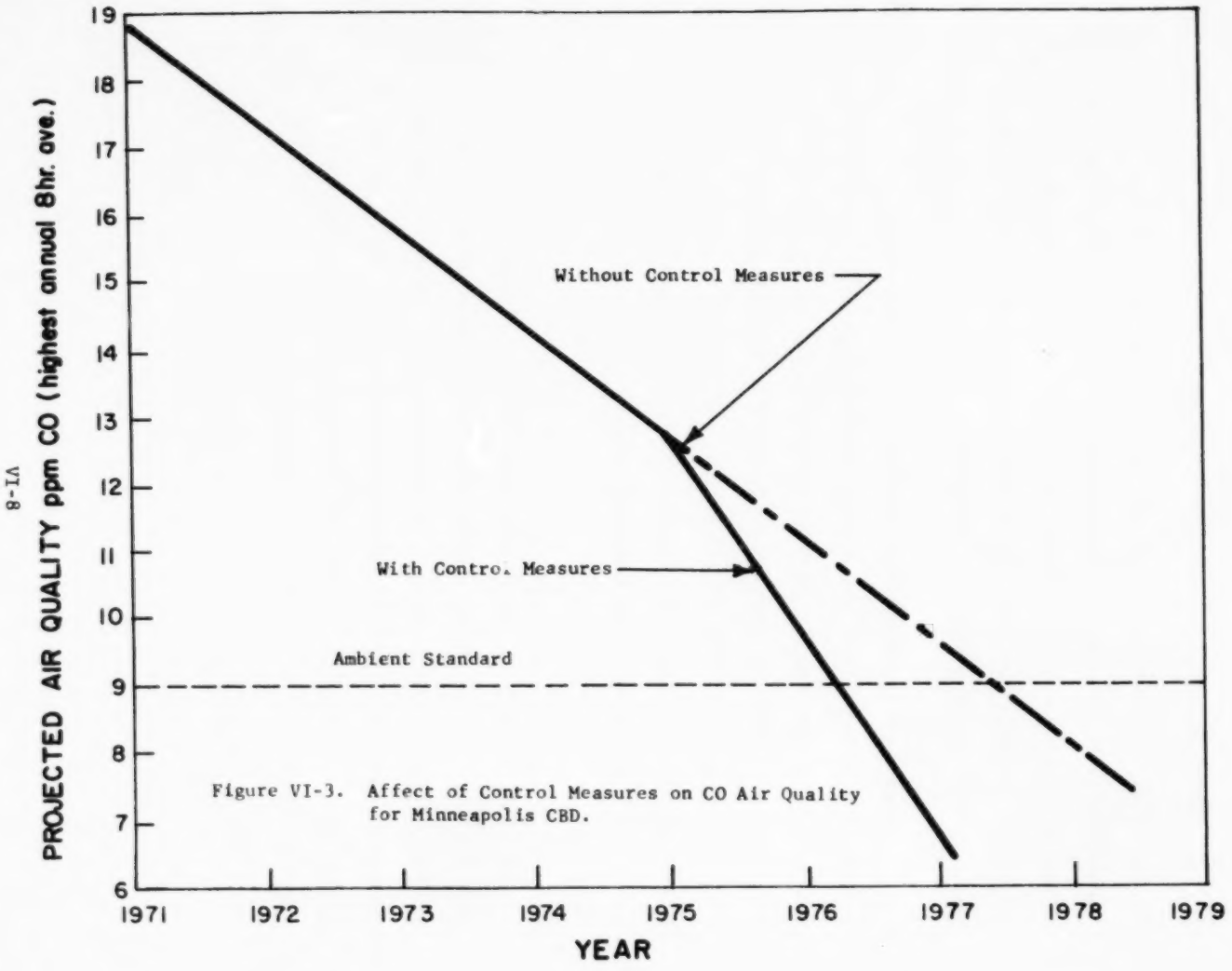

Figure VI-3. Affect of Control Measures on CO Air Quality for Minneapolis CBD.

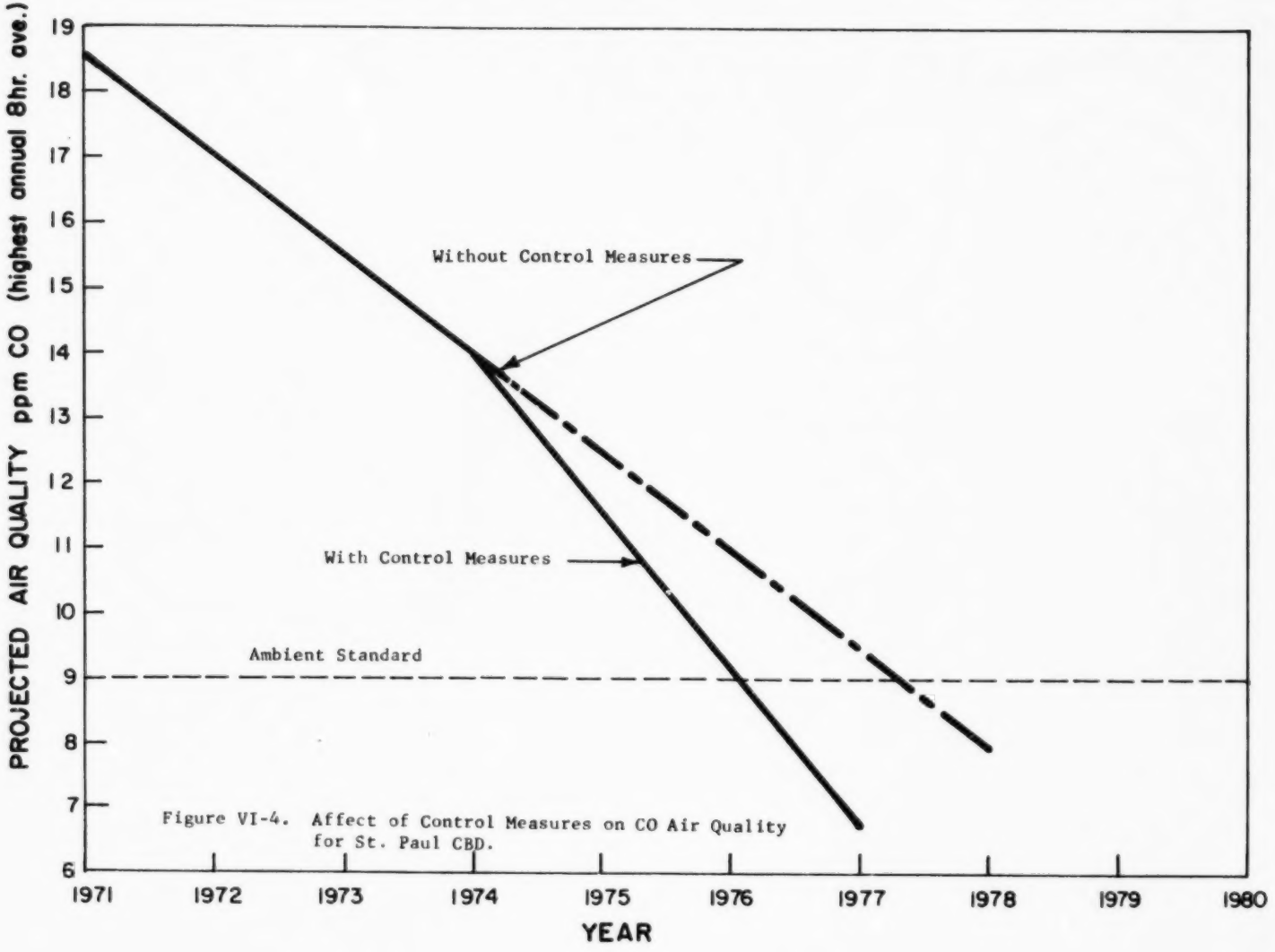

Figure VI-4. Affect of Control Measures on CO Air Quality for St. Paul CBD.

APPENDIX A

LIST OF PERSONS CONTACTED ABOUT THE IMPLEMENTATION OF CANDIDATE STRATEGIES

Bob Benke, Transportation Planner for Highway Department

Don Cosgrove, St. Paul City Planning Department

Thomas Duffee, Downtown Council, Minneapolis

Chuck Ewert (with Consultant) Operation 85, St. Paul

John Jameson, Transit Commission

Burt Johnson, Minnesota Highway Patrol

Dave Koski, Minneapolis, Traffic Engineer

Fritz Marshall, State Highway Department

Dick Meyer, Metro Council

Bob Moffet, City Coordinator's Office, Minneapolis

Bob Peterson, Traffic Engineer, St. Paul

Bob Ready, Minneapolis, City Planning Department

APPENDIX B

EVALUATION OF THE CANDIDATE STRATEGY REJECTED FOR MINNEAPOLIS-ST. PAUL: VEHICLE PERFORMANCE INSPECTION

The vehicle performance inspection discussed with the candidate strategies for Minneapolis-St. Paul was rejected, in large part because of the difficulty of implementing such a program. The major local obstacles to its implementation are discussed here.

Legal Authorization and Requirements

The Metro Clean Air Council will propose the necessary legislation in the January session for a mandatory engine performance inspection program. The bill will include provisions that vehicles be given an idle test within 20 days of their sale (new or used) and annually. A similar bill has been proposed twice before and failed. Although it has higher level commitment than before, it is not expected to pass.

Financial Requirements

The cost of a vehicle performance inspection would be high. If two-man teams were used, each testing about 50 cars per day in conjunction with the safety inspection, 80 to 100 people would be needed for only that portion of the cars that receive a safety inspection. Additional funds would be needed for equipment, certification of garages, enforcement and follow-up. Some of this money could come from the state highway funds, but the Minnesota Pollution Control Agency would be expected to support it in part.

Management and Enforcement Responsibility

The logical candidate for managing and enforcing a vehicle inspection program would be the Highway Patrol within the State Department of Public Safety, since enforcement would clearly require a uniformed officer. However, this agency is not interested in undertaking an engine performance inspection, since they see it serving public health purposes and not safety purposes. This leaves the state without an appropriate agency for implementing the program.

Economic Impact

An engine performance inspection has several problems in Minnesota of an economic nature. An important consideration is the difficulty of finding a garage to make the necessary repairs. While this is not difficult in the major metropolitan centers, there is a shortage of repair garages of any type in the more rural parts of the state. This could make the cost of repairs in rural areas very high.

A vehicle inspection program also discriminates against the poor, since they are usually the drivers of older cars which have maintenance problems and require repair. If the repairs were expensive, the program could curtail their mobility.

User Acceptance

The vehicle performance tests would take at least 10 minutes if it were an idle test, and longer for other types of tests. On either a spot check on mandatory basis, this could aggravate drivers and turn them against the program. This problem, combined with the high cost of operating the program and the vehicle owner's need to make sometimes costly repairs could make it very unpopular.

APPENDIX C

EMISSIONS WITHIN MINNEAPOLIS AND ST. PAUL CBD'S
WITHOUT CONTROL STRATEGIES

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1971

REGION NO. 3 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1959 TO 1972

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	2.200	24947.52	11294.32	3062.51	1392.05	59.19	26.90	27969.21	12713.28
2	0.800	8875.13	11093.91	1109.36	1386.70	21.63	27.04	10006.12	12507.65

Note: Zone 1 = Minneapolis CBD
Zone 2 = St. Paul CBD

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1971

REGION NO. 3 POLLUTANT SPECIES IS HYDROCARBONS

MODEL YEARS CONSIDERED IS FROM 1959 TO 1972

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	2.200	3008.94	1367.70	535.90	243.59	9.74	4.43	3554.58	1615.72
2	0.800	1063.55	1354.44	195.57	244.46	3.56	4.45	1282.68	1603.34

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1977

REGION NO. 3 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1965 TO 1978

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	2.200	11456.03	5207.29	2643.46	1201.57	71.84	32.66	14171.33	6441.51
2	0.800	4099.81	5124.76	961.61	1202.01	26.12	32.66	5087.54	6359.42

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1977

REGION NO. 3 POLLUTANT SPECIES IS HYDROCARBONS

MODEL YEARS CONSIDERED IS FROM 1965 TO 1978

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	2.200	1276.78	580.35	433.25	196.93	11.82	5.37	1721.85	782.66
2	0.800	460.25	575.31	158.50	198.13	4.30	5.37	623.05	778.81

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1976

REGION NO. 3 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1966 TO 1979

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI
1	2.200	9365.43	4257.02	2514.32	1142.87	74.15	33.70	11953.90	5433.59
2	0.900	3352.90	4191.12	914.08	1142.60	26.96	33.70	4293.94	5307.42

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1978

REGION NO. 3 POLLUTANT SPECIES IS HYDROCARBONS

MODEL YEARS CONSIDERED IS FROM 1956 TO 1979

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	2.200	1070.05	486.39	410.58	186.63	12.20	5.54	1492.83	678.56
2	0.800	385.81	482.26	150.03	187.54	4.43	5.54	540.28	675.35

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1979

REGION NO. 3 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1967 TO 1980

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	2.200	7569.73	3440.79	2385.29	1084.22	76.52	34.78	10031.53	4559.79
2	0.800	2711.63	3389.54	868.21	1085.26	27.82	34.77	3607.67	4509.58

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CITY OF MINN/ST PAUL CALENDAR YEAR IS 1979

REGION NO. 3 POLLUTANT SPECIES IS HYDROCARBONS

MODEL YEARS CONSIDERED IS FROM 1967 TO 1980

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	2.200	873.49	397.04	389.45	177.02	12.59	5.72	1275.53	579.79
2	0.800	315.04	393.80	142.40	178.00	4.58	5.72	462.02	577.52

APPENDIX D

EMISSIONS WITHIN URBAN ACTIVITY DISTRICTS (UAD'S) IN MINNEAPOLIS AND ST. PAUL METROPOLITAN AREAS

Note:	Zone #	≡	UAD
Minneapolis	1		52
	2		53
	3		54
	4		55
	5		56
	6		63
	7		64
	8		65
	9		66
	10		67
	11		68
	12		69
St. Paul	13		79
	14		80
	15		81
	16		82
	17		83
	18		89
	19		90
	20		91
	21		92
	22		93

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1971

REGION NO. 3 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1959 TO 1972

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	5.280	5441.68	1030.62	623.67	118.12	38.84	7.36	6104.19	1156.10
2	8.600	12169.34	1415.04	1394.68	162.17	90.58	10.53	13654.60	1587.74
3	5.040	10106.74	2005.31	1158.28	229.82	83.21	16.51	11348.23	2251.63
4	5.480	13790.92	2516.59	1580.52	288.42	97.34	17.76	15468.78	2822.77
5	5.960	15970.82	2679.67	1830.34	307.10	120.03	20.14	17921.19	3006.91
6	1.400	5455.07	3896.48	625.14	446.53	41.96	29.97	6122.17	4372.98
7	5.560	19319.31	3474.70	2214.09	398.22	152.24	27.38	21685.63	3900.29
8	5.600	10155.53	1813.49	1163.84	207.83	77.78	13.89	11397.15	2035.21
9	5.200	8070.59	1552.04	924.93	177.87	63.86	12.28	9059.37	1742.19
10	4.080	6840.69	1676.64	783.93	192.14	57.15	14.01	7681.77	1882.79
11	2.600	6903.33	2655.13	791.18	304.30	58.54	22.51	7753.04	2981.94
12	6.200	8804.84	1420.14	1009.10	162.76	71.11	11.47	9885.04	1594.36
13	6.000	8902.09	1483.68	1485.48	247.58	72.62	12.10	10460.18	1743.36
14	3.120	4899.15	1570.24	817.49	262.01	40.76	13.06	5757.39	1845.32
15	6.600	8411.14	1274.42	1561.55	236.60	63.96	9.69	10036.66	1520.71
16	3.200	9704.57	3032.68	1619.38	506.05	82.76	25.86	11406.70	3564.59
17	6.880	18761.82	2727.01	3130.68	455.04	136.15	19.79	22028.65	3201.84
18	3.840	4514.44	1175.64	753.28	196.17	35.23	9.17	5302.95	1380.98
19	13.480	8934.01	662.76	1490.81	110.59	72.11	5.35	10496.92	778.70
20	4.430	7795.28	1740.02	1300.76	290.35	62.78	14.01	9158.82	2044.38
21	7.280	8047.50	1105.43	1342.87	184.46	60.43	8.30	9450.80	1298.19
22	3.800	4908.48	1291.70	819.09	215.55	35.72	9.40	5763.28	1516.65

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1971

REGION NO. 3 POLLUTANT SPECIES IS HYDROCARBONS

MODEL YEARS CONSIDERED IS FROM 1959 TO 1972

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	5.280	940.17	178.06	146.98	27.84	6.39	1.21	1093.54	207.11
2	8.600	2154.79	250.56	335.64	39.03	14.90	1.73	2505.33	291.32
3	5.040	1833.52	373.71	290.27	57.59	13.69	2.72	2187.47	434.02
4	5.480	2380.77	434.45	372.96	68.06	16.01	2.92	2769.74	505.43
5	5.960	2836.24	475.88	441.17	74.02	19.74	3.31	3297.14	553.21
6	1.400	980.96	700.69	152.22	108.73	6.90	4.93	1140.09	814.35
7	5.560	3515.40	632.27	544.12	97.86	25.04	4.50	4084.56	734.63
8	5.600	1817.25	324.51	281.98	50.35	12.79	2.28	2112.02	377.15
9	5.200	1467.67	282.24	226.93	43.64	10.50	2.02	1705.11	327.90
10	4.080	1283.31	314.54	197.41	48.39	9.40	2.30	1490.12	365.23
11	2.600	1307.21	502.77	200.86	77.25	9.63	3.70	1517.70	583.73
12	5.200	1622.21	261.65	250.43	40.39	11.70	1.89	1884.33	303.92
13	6.000	1625.08	270.85	365.92	60.99	11.94	1.99	2002.94	333.82
14	3.120	902.81	289.36	202.83	65.01	6.70	2.15	1112.34	356.52
15	6.600	1477.70	223.89	372.69	56.47	10.52	1.59	1860.92	281.96
16	3.200	1812.40	566.38	406.16	126.93	13.61	4.25	2232.18	697.56
17	6.880	3226.19	468.92	735.21	106.86	22.39	3.26	3983.79	579.04
18	3.840	807.50	210.29	182.75	47.59	5.79	1.51	996.05	259.39
19	13.480	1621.31	120.28	365.47	27.11	11.66	0.88	1998.63	148.27
20	4.480	1412.91	315.38	318.53	71.10	10.33	2.30	1741.76	388.79
21	7.280	1408.26	193.44	319.84	43.93	9.94	1.37	1738.04	238.74
22	3.800	844.11	222.14	192.28	50.60	5.87	1.55	1042.27	274.28

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1977

REGION NO. 3 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1965 TO 1978

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	5.280	2561.81	485.19	629.36	119.20	46.07	8.72	3237.23	613.11
2	8.600	5728.69	666.13	1423.28	165.50	107.44	12.49	7259.40	844.12
3	5.040	4855.29	963.35	1235.69	245.18	98.68	19.58	6189.66	1228.11
4	5.480	6487.21	1183.80	1589.54	290.06	115.44	21.07	8192.18	1494.92
5	5.960	7548.45	1266.52	1878.17	315.13	142.36	23.89	9568.97	1605.53
6	1.400	2583.04	1845.03	646.51	461.79	49.78	35.56	3279.33	2342.38
7	5.560	9168.84	1649.07	2308.69	415.23	180.57	32.48	11658.09	2096.78
8	5.600	4807.09	858.41	1201.82	214.61	92.25	16.47	6101.16	1089.49
9	5.200	3831.47	736.82	965.87	185.75	75.78	14.57	4873.12	937.14
10	4.080	3261.39	799.36	833.91	204.39	67.78	16.61	4163.08	1020.36
11	2.600	3295.36	1267.45	845.93	325.36	69.41	26.70	4210.70	1619.50
12	6.200	4185.67	675.11	1060.75	171.09	84.35	13.61	5330.77	859.80
13	6.000	4225.85	704.31	1552.35	258.73	86.13	14.36	5864.33	977.39
14	3.120	2128.69	682.27	787.23	252.32	48.35	15.50	2964.27	950.09
15	6.600	3970.60	601.61	1433.01	217.12	75.88	11.50	5479.49	830.23
16	3.200	4624.00	1445.00	1718.37	536.99	98.17	30.68	6440.54	2012.67
17	6.880	8825.80	1282.82	3148.93	457.69	161.48	23.47	12136.21	1763.98
18	3.840	2135.49	556.12	775.69	202.00	41.80	10.89	2952.98	769.01
19	13.480	4237.32	314.34	1552.21	115.15	85.52	6.34	5875.04	435.83
20	4.480	3578.84	798.85	1310.73	292.57	72.17	16.11	4961.74	1107.53
21	7.280	3795.29	521.33	1365.39	187.55	71.68	9.85	5232.36	718.73
22	3.800	2309.48	607.76	824.47	216.97	42.35	11.14	3176.31	835.87

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1977

REGION NO. 3 POLLUTANT SPECIES IS HYDROCARBONS

MODEL YEARS CONSIDERED IS FROM 1965 TO 1978

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	5.280	381.15	72.19	124.76	23.63	7.58	1.43	513.48	97.25
2	8.600	870.07	101.17	285.52	33.20	17.67	2.05	1173.26	136.43
3	5.040	762.67	151.32	251.99	50.00	16.23	3.22	1030.90	204.54
4	5.480	966.17	176.31	315.85	57.64	18.99	3.46	1301.01	237.41
5	5.960	1147.06	192.46	376.63	63.19	23.42	3.93	1547.11	259.58
6	1.400	396.29	283.07	130.31	93.08	8.19	5.85	534.79	381.99
7	5.560	1418.65	255.15	467.22	84.03	29.70	5.34	1915.56	344.53
8	5.600	734.10	131.09	241.40	43.11	15.17	2.71	990.67	176.91
9	5.200	592.05	113.86	195.11	37.52	12.46	2.40	799.62	153.77
10	4.080	516.27	126.54	170.68	41.83	11.15	2.73	698.10	171.10
11	2.600	525.55	202.13	173.87	66.87	11.42	4.39	710.84	273.40
12	6.200	653.66	105.43	215.63	34.78	13.87	2.24	883.16	142.45
13	6.000	655.38	109.23	314.45	52.41	14.17	2.36	983.99	164.00
14	3.120	341.93	109.59	162.69	52.14	7.95	2.55	512.58	164.29
15	6.600	597.88	90.59	285.66	43.28	12.48	1.89	896.02	135.76
16	3.200	729.27	227.90	350.92	109.66	16.15	5.05	1096.33	342.60
17	6.880	1308.71	190.22	623.26	90.59	26.56	3.86	1958.54	284.67
18	3.840	326.48	85.02	156.15	40.67	6.88	1.79	489.51	127.48
19	13.480	654.21	48.53	313.68	23.27	14.07	1.04	981.96	72.85
20	4.480	552.16	123.25	264.74	59.09	11.87	2.65	828.77	184.99
21	7.280	570.31	78.34	272.18	37.39	11.79	1.62	854.28	117.35
22	3.800	342.34	90.09	163.08	42.92	6.97	1.83	512.39	134.84

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APPENDIX E

IMPACT OF STRATEGIES ON EMISSIONS IN MINNEAPOLIS AND ST. PAUL CBD'S

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1977

REGION NO. 3 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1965 TO 1979

LENGTH OF TIME PERIOD IS 12 hours

VEHICLE CATEGORY →		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL		
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	Strategi Employed
Minn. CBD	2.200	10557.24	4798.74	2548.18	1203.72	71.84	32.66	13277.26	6035.12	1
	2.200	7905.32	3593.33	2085.64	948.02	71.84	32.66	10062.79	4574.00	142
St. Paul CBD	0.200	3695.74	4619.68	961.61	1202.01	26.12	32.66	4683.47	5854.34	1
	0.200	2830.11	3537.64	771.53	964.41	26.12	32.66	3627.76	4534.70	142

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1977

REGION NO. 3 POLLUTANT SPECIES IS HYDROCARBONS

MODEL YEARS CONSIDERED IS FROM 1965 TO 1978

LENGTH OF TIME PERIOD IS 12 hours

VEHICLE CATEGORY →		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL		
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	Strategies Employed
Minn.	2.200	1176.61	534.82	434.03	197.28	11.92	5.37	1622.45	737.48	1
CBD	2.200	991.03	450.47	371.20	168.73	11.82	5.37	1374.04	624.57	142
St. Paul	2.200	414.99	518.61	158.56	196.13	4.30	5.37	577.69	722.11	1
CBD	2.200	352.32	440.40	136.57	170.72	4.30	5.37	493.19	616.48	142

APPENDIX F

EMISSIONS WITHIN KSTP TOWER AREA WITHOUT CONTROL STRATEGIES

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1971

REGION NO. 3 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1959 TO 1972

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	1.130	2322.31	2055.14	229.20	202.83	14.70	13.00	2566.20	2270.98

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1971

REGION NO. 5 POLLUTANT SPECIES IS HYDROCARBONS

MODEL YEARS CONSIDERED IS FROM 1959 TO 1972

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	1.130	403.03	356.66	53.90	47.70	2.42	2.14	459.35	406.50

CITY OF MINN/ST PAUL CALENDAR YEAR IS 1977

REGION NO. 3 POLLUTANT SPECIES IS CARBON MONOXIDE

MODEL YEARS CONSIDERED IS FROM 1965 TO 1976

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY		HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	1.130	1110.00	966.14	238.32	210.90	17.76	15.71	1372.67	1214.75

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CITY OF MINN/ST PAUL CALENDAR YEAR IS 1977

REGION NO. 3 POLLUTANT SPECIES IS HYDROCARBONS

MODEL YEARS CONSIDERED IS FROM 1965 TO 1976

LENGTH OF TIME PERIOD IS 12 HOURS

VEHICLE CATEGORY -		LIGHT DUTY			HEAVY DUTY		OTHER		TOTAL	
ZONE NO.	AREA (SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)	EMISSIONS (KGM)	EMISSION DENSITY (KGM/SQ.MI)
1	1.130	165.89	146.80	46.95	41.55	2.92	2.58	215.76	190.94

APPENDIX G

PASSENGER CAR REGISTRATION DATA FOR AQCR 131
FROM WHICH VEHICLE AGE DISTRIBUTION WAS DERIVED

REGISTERED PASSENGER CARS IN MINNESOTA AS OF JULY 1, 1970

Year \ County	Anoka	Carver	Dakota	Hennepin	Ramsey	Scott	Washington	Total
1970	1,157	857	3,421	51,970	22,394	1,845	2,343	83,987
1969	1,589	1,058	3,728	60,373	26,179	2,347	2,738	98,012
1968	1,638	1,013	3,748	55,335	25,515	2,349	2,600	92,198
1967	1,586	1,081	3,687	53,498	24,673	2,206	2,612	89,343
1966	1 672	1,170	3,704	40,732	23,721	2,227	2,737	84,963
1965	1,616	1,115	3,817	49,453	24,350	2,095	2,829	85,275
1964	1,354	921	2,890	38,128	18,950	1,699	2,353	66,295
1963	1,321	782	2,563	33,684	17,089	1,417	2,003	58,859
1962	1,071	628	2,103	28,083	14,152	1,066	1,657	48,760
1961	793	410	1,429	18,444	9,497	767	1,196	32,546
1960	658	359	1,217	14,783	7,844	629	1,043	26,533
1959	364	245	637	7,897	4,105	372	614	14,234
1958	178	125	325	3,718	2,080	189	313	6,928
1957	230	128	368	4,354	2,270	228	319	7,897
1956	148	92	254	2,968	1,505	145	227	5,339
1955	128	100	234	2,633	1,261	126	190	4,672
Prior to 1955	356	323	618	6,691	3,251	373	509	12,121
Year not Given	3	0	3	84	38	1	1	130
TOTAL	15,862	10,407	34,756	481,828	228,874	20,081	26,284	818,092